सत्यमेव जयते

Ministry of Road Transport & Highways
Government of India

Capacity Development Project on Highways in Mountainous Regions

GUIDELINE FOR OPERATION AND MAINTENANCE

Published by :
Indian Roads Congress

On behalf of the Government of India,
Ministry of Road Transport & Highways
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Foreword

The road network plays a vital road in the overall development of a country by providing the access to employment, social, health and education. India has a vast area in hilly regions consisting of the Himalayan region from North to North-East, the Central Highlands of Aravali, Vindhya & Satpura ranges, the Sahyadri (Western ghats) and the Eastern ghats. Providing all weather connectivity road network in these hilly regions with extreme climatic conditions, difficult and hazardous terrain, topography and high altitude areas is a tough task. The Ministry of Road Transport & Highways has always taken steps towards the betterment of road transport throughout the country and tackling the problem of roads in hilly regions of the country is one such step.

This Guideline for Operation and Maintenance of Hill Roads was prepared through the "Capacity Development Project on Highways in Mountainous Regions," bilaterally implemented by MoRTH and JICA. The project started in 2016 and prepared five guidelines that are essential for sustainable development of hill roads in India. Among the five guidelines, this Operation and Maintenance of Hill Roads Guideline focuses on the following technical topics:

- Concept and method for appropriate traffic management on hill roads comprised of (i) Advanced Traffic Management System (ATMS) including Traffic Control Center (TCC) as the center commando of traffic management, (ii) Early Warning System (EWS) which is the traffic control under disastrous weather conditions, and (iii) the regulations for overloaded / oversized vehicles.
- Operation and maintenance of mountain tunnels including the arrangement and design of emergency facilities, interior facing as well as Tunnel Control Center (TCC).
- Philosophy of the PDCA cycle and countermeasures in terms of road safety in work zones and toll plazas on hill roads.
- Key points and practical guidance for appropriate inspection, assessment of distress and deterioration based on the principle of preventive maintenance for hill roads including typical road structures such as slopes, tunnels, bridges etc.
- Procedures, planning, and implementation of maintenance works.
- Good practice and state-of-the-art technologies in Japan in terms of operation and maintenance of hill roads.

The Japanese team as well as the Indian team, especially the Experts from JICA, Counterpart Officials from MoRTH, NHAI & NHIDCL, the Project Director and the Project Team, are to be complimented for their commendable effort in producing these guidelines. Their contribution would go a long way towards the sustainable development of roads in the hilly regions of the country.

The 27th day of January 2022

(I. K. Pandey)
Director General (Road Development) & Special Secretary
Ministry of Road Transport & Highways
Government of India

PREFACE

India is a vast country with diverse geological, climatic regions. Roads are one of the important elements of transport infrastructure for land surface movement of passengers, goods, ammunition & army –intercity, intracity, rural areas and neighboring counties. Indian road network passes through different terrains including hills and mountains. Mountainous regions consist of Himalayan region from North to North-East, the Central Highlands of Aravalli, Vindhya and Satpura ranges, Western and Eastern Ghats.

These mountainous regions, generally, have extreme climatic condition, difficult and hazardous terrain, topography and vast high-altitude areas. Roads in mountainous areas are often composed of multiple civil engineering structures including bridges and tunnels, and proper maintenance is essential to maintain the road function as a network. The Hill regions including the road networks are affected more frequently by floods due to torrential rainfall, landslides, snow avalanche etc. which compel many sections of road network closed during rainy season and winter season. However, accountability for providing safe, reliable and user comfortable road network ultimately rests with the Government departments.

For hill roads IRC has published numerous guidelines, manuals, codes, etc viz IRC: 52, IRC:48, IRC: SP:91; IRC: SP:108: IRC: SP:113, IRC: 5; etc for guidance and adoption by highway professional & road departments.

Ministry of Road Transport & Highways (MORTH), took up the initiative to frame Guidelines for Planning, Slope protection, Mountain bridge, Mountain tunnel & Operation and maintenance of highways in mountainous regions through technical cooperation from Japan International Cooperation Agency (JICA) in 2016. JICA took site visits of hilly roads in India, collected site problem statement, interacted with Indian experts from MORTH, NHAI, NHIDCL, PWD, IRC, etc and also conducted seminars, webinars, meetings, etc before finalization of following 5 documents;

- Guidelines for Planning
- Guidelines for Slope protection and embankment with advanced technology
- Guidelines for Mountain bridge with advanced Technology

- Guidelines for Tunnel on Arterial Roads in Hill Areas
- Guidelines for Operation and maintenance

The Guidelines for Highways in Mountainous Regions, as prepared by JICA mainly highlights appropriate planning, design principles for promoting safety conscious planning and design of roads, embankment, slope & its operation & maintenance aspect and will go a long way in guiding the highway engineers and planners to make our, hill roads, tunnels, bridges, safer, comfortable and of international standards.

It is quite natural, this JICA publications cannot be expected to cover all the subjects and details of highway engineering and as such should not be considered as a substitute for the Standards and Specifications as well as Codes of Practice.

The intent of this publications is to provide guidance to the engineers with the critical aspects of development of Highways in Mountainous Regions. These guidelines are dynamic in nature and the users, based on their experience, give appropriate feedback so as to enable the Guidelines to be revised/improved from time to time.

(S K Nirmal)
Director General (Road Development) and Special Secretary
Ministry of Road Transport and Highways &
Secretary General, IRC

Dated July, 2022

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List of Abbreviations and Acronyms

AADT	Average Annual Daily Traffic
ATCC	Automatic Traffic Counter cum Classifier
ATIS	Advanced Traffic Information System
ATMS	Advanced Traffic Management System
BRO	Border Roads Organization
C/P	Counterpart
C/R	Completion Report
CCR	Central Control Room
CCTV	Closed Circuit Television
CDMA	Code Division Multiple Access
DPC	Disaster Prevention Center
DPR	Detailed Project Report
ECB	Emergency Call Box
ELB	Earth Leakage Breaker
EPC	Engineering, Procurement and Construction contract
ERSS	Emergency Report Support System
EWS	Early Warning System
FCC	Facility Control Center
GNSS	Global Navigation Satellite System
GoI	Government of India
GSM	Global System for Mobile Communications
HAM	Hybrid Annuity Model
HAR	Highway Advisory Radio
HDM-4	Highway Development and Management System
HTMS	Highway Traffic Management System
IAHE	Indian Academy for Highway Engineer
IBMS	Indian Bridge Management System
IRC	Indian Road Congress
ITS	Intelligent Transportation System
JCC	Joint Coordination Committee
JICA	Japan International Cooperation Agency
LCC	Life Cycle Cost
LCDs	Liquid Crystal Displays
LEDs	Light Emitting Diodes
MET	Meteorological Data System
MoRTH	Ministry of Road Transport and Highways
MS	Monitoring Sheet

NHDP	National Highways Development Project
NHIDCL	National Highways and Infrastructure Development Corporation Ltd.
NMS	Network Management System
OFC	Optical Fiber Cable
OJT	On-the-Job Training
O/M	Operation and Maintenance
OSV	On Site Visualization system
PDCA	Plan-Do-Check-Act cycle
PDM	Project Design Matrix
PIJF	Polythene Insulated Jelly Filled Cable
PMS	Pavement Management System
PO	Plan of Operation
PPP	Public Private Partnership
PWD	Public Works Department
R/D	Record of Discussion
RFID	Radio Frequency Identifier
RoW	Right-of-Way
SOPs	Standard Operation Procedures
SPT	Standard Penetration Test
TCC	Traffic Control Center
TG	Technical Group
TN	Tunnel
TTES	Travel Time Estimation System
TOT	Training of Trainers
UPS	Uninterrupted Power Supply
VIDS	Video Incident Detection System
VMS	Variable Message Sign
WHO	World Health Organization
WIM	Weigh-in-Motion
WTMP	Work Zone Traffic Management Plan
WP	Work Plan

CHAPTER 1 INTRODUCTION

1.1 Background

India has about 5.89 million km of the road network, which is the second-largest in the world, according to Annual Report 2018-19 published by the Ministry of Road Transport, and Highways (MoRTH). Since 1998, the government has developed a national highway network throughout India in a phased manner under the whole-India project of the National Highways Development Project (NHDP). Major corridors, such as Golden Quadrilateral, NS&EW Corridors, connecting major cities and regions, have been constructed and upgraded in the project. In 2017, a new cap program, named Bharatmala Pariyojana, was released, which focuses on optimizing the efficiency of freight and passenger movement across the nation.

In recent years the government has also been paying special attention to the development of national highways in mountainous areas in terms of improvement of local connectivity as well as national border connectivity. Due to the challenging and adverse circumstances posed by such as climate and geology, hill roads are vulnerable to disaster. Some of the hill roads have critical bottlenecks, hindering the economic development of the regions and quality of life. Under such circumstances, the technical cooperation project, “Capacity Development Project on Highways in Mountainous Regions” was has been conducted by mutual cooperation between India and Japan. Five guidelines have been developed in the area of (1) planning, (2) slope protection, (3) tunnel, (4) bridge, and (5) operation and maintenance.

1.2 Structure of Operation and Maintenance Guideline

Guideline for Operation and Maintenance is largely divided into two parts as its name of the guideline; Operation and Maintenance.

The operation of this guideline aims to present various aspects of road operation methods in a comprehensive manner, which are recommended to be applied to arterial roads in mountainous regions. The operation part is comprised of the following four chapters. The section 1.3 below provides a brief summary of each section.

Chapter 1: Introduction (this chapter)
Chapter 2: Traffic Management on Hill Roads
Chapter 3: Tunnel Operation
Chapter 4: Safety Measures on Hill Roads

Maintenance of this guideline, on the other hand, aims to provide practical know-how and adequate approaches required for the maintenance of mountainous highways in a comprehensive manner. The maintenance part is comprised of the following two chapters. The section 1.3 below provides a brief summary of each section.

Chapter 5: Inspection and Monitoring

Chapter 6: Maintenance Planning and Works

This guideline provides not only general philosophy and framework but also specific methods and approaches as far as possible for practical usage on actual sites of hill roads in India.

1.3 Outline of Each Chapter

1.3.1 Chapter 2: Traffic Management on Hill Roads

This chapter presents three core parts comprised of (i) Advanced Traffic Management System (ATMS) and their application to hill roads, (ii) Early Warning System (EWS), and (iii) Control of Overloaded Oversized Vehicles.

(i) ATMS is typically classified into three steps in terms of its system and process; which are (a) information collection, (b) processing at a traffic management center (the Center), and (c) information dissemination to road users. (a) Information collection includes patrolling, Video Surveillance System (CCTV), Video Incident Detection System (VIDS), Emergency Communication System, Meteorological Data System, Weigh-in-Motion& Weigh Bridge System, Automatic Traffic Counter cum Classifier (ATCC), and Mobile Radio Communication System. (ii) processing at the Center includes Traffic Control Center (TCC), Facility Control Center, Disaster Prevention Center, and Data Transmission System. (iii) Information dissemination to road users deliberates Variable Message Signs (VMS), Portable VMS on vehicles, Vehicle Actuated Speed Display, Travel Time Estimation System (TTES), Highway Advisory Radio (HAR), and Internet or Mobile Services.

(ii) This section presents an outline of the Early Warning System and introduces its common practice, which has been conducted in Japan and then delineates necessary processes to decide a threshold or criteria value for the implementation of an early warning system. Early Warning System aims to regulate and close a concerned section proactively before the disaster happens, based on real-time weather information. This system has been used on hill roads in Japan for decades to secure further safety of road users. A threshold or criteria value is determined beforehand by the data of disaster records and the history of rainfall records. For the operation of an early warning system, weather stations are installed along a highway for a road operator to monitor real-time weather conditions, especially rainfall. In areas where weather condition changes frequently, such as steep mountain range areas, the interval of weather stations are designed shorter than those in other areas. According to the data from the weather station, a road operator can swiftly judge to conduct patrol and/or road closure.

(iii) Overloaded or oversized vehicles which violate Motor Vehicles Act have posed a major threat to the surrounding environment, road safety, and traffic smoothness. Hill roads are not an exception. This chapter presents the basic framework and methodologies of countermeasures against overloaded and oversized vehicles.

1.3.2 Chapter 3: Tunnel Operation

A road tunnel is an indispensable structure along with slope, embankment, and bridge in the context of mountainous highways. Since a tunnel is a fundamentally closed space and vehicles are flammable due to the source of the engine, an accident inside the tunnel may lead to a serious disaster once it happens. In this regard, proper and swift tunnel operation is vital to prevent a critical issue. Emergency facilities such as fire extinguishers, push bottom alarms aside from emergency tunnels shall be easily utilized by road users. Also, once an accident happens inside the tunnel, it often needs close collaboration with related agencies like firefighters, police, defense agencies, etc.

This chapter describes what kinds of tunnel emergency facilities are necessary and where they need to be installed. Their intended roles, purposes, and standard arrangements according to the ranks of tunnels, which are determined according to traffic volume and length of the tunnel, are also presented. Moreover, tunnel interior facing is also described, which intended purposes are to improve the visual environment of drivers, comfortableness of drivers, traffic safety, and lighting effect.

1.3.3 Chapter 4: Safety Measures on Hill Roads

Road safety is one of the common social problems in the world, and it is not an exception on mountainous highways. There are some effective methods to tackle road safety issues by proper maintenance, provision of adequate information to road users, and improving black spots through a road safety audit. This chapter explains the philosophy of the PDCA (Plan-Do-Check-Act) cycle, road safety audit, specific measures of road safety, as well as safety in work zones and toll plazas. Specific countermeasures include high visibility road marking, lighting installation, self-luminous delineator, anti-glare device, porous asphalt pavement, rumble strip using the thin-layer surface pavement, reinforced and wire type of guard rail, diverging nose indicator, and so forth.

1.3.4 Chapter 5: Inspection and Monitoring

This chapter presents all elements of inspection and monitoring, from the basic framework of inspection, inspection planning, methods, and frequency, as well as a continuous observation on high-risk slopes during construction, operation, and maintenance. Easiness of inspection should be considered in an earlier stage of planning and design, which are also described. This chapter also presents practical guidance of assessment, including how to categorize distress and deterioration for road administrators in a standardized manner in order to prioritize remedial measures against many maintenance locations. In this regard, standard ranking criteria of damage in association with the degree and size of the defect is elaborated in this chapter. State-of-the-art inspection methods are also introduced.

Moreover, this chapter also explains recommended key points of inspection for inspectors to keep in mind during the inspection of slope structures. By paying attention to the presented key points in the chapter, inspectors are expected to act earlier in a smoother manner before a small and minute abnormality leads to critical issues. In case an inspection judge that investigation is required to understand the current status, damage, and deformation concerning the structure in detail, appropriate approaches and methods should be conducted.

1.3.5 Chapter 6: Maintenance Planning and Works

Chapter6 describes maintenance works, including its procedures, planning, and implementation. Regardless of continuous observation and monitoring, slope failure or collapse may occur due to such abnormal weather. This chapter also explains how to respond to such a disaster, including first response and permanent rehabilitation works.

1.4 Related Guidelines and Manuals

Indian Road Congress (IRC) and the Ministry of Road Transport and Highways (MoRTH) have published many guidelines and manuals for operation and maintenance areas. Readers may refer to those documents, if necessary, which include the followings:

- IRC-24-2010 : Standard specifications and code of practice for road bridges
- IRC-67-2012 : Code of Practice for road signs
- IRC-82-1982 : Code of Practice for Maintenance of Bituminous Surfaces of Highways
- IRC:SP:19-2001 : Manual for Survey, Investigations, and Preparation of Road Projects
- IRC:SP:35-1990 : Guidelines for Inspection and Maintenance of Bridges
- IRC:SP:48-1998 : Hill Road Manual
- IRC:SP:52-1999 : Bridge Inspector's Reference Manual
- IRC:SP:54-2000 : Project Preparation Manual for Bridges
- IRC-SP-55-2014 : Guidelines on traffic management in work zones
- IRC-SP-83-2008 : Guidelines for maintenance, repair, and rehabilitation of cement concrete pavements
- IRC-SP-91-2010 : Guidelines for Road Tunnels
- IRC-SP-99-2013 : Manual of Specifications and Standards for Expressways
- IRC-SP-106-2015 : Engineering guidelines on landslide mitigation measures for Indian roads
- MoRTH-1983 Manual for maintenance of roads
- MoRTH-2000 Pocket book for bridge engineers
- MoRTH-2002 Pocket book for highway engineers

CHAPTER 2 TRAFFIC MANAGEMENT ON HILL RORDS

2.1 Background

India has one of the largest road networks in the world, which length is around 5.48 million km-length including approx. 120,000km-length of National Highways / Expressways (Annual Report 2017-2018, MoRTH). The road network is an important transportation infrastructure which shares 85% of passenger transport and 65% of freight transport. [1]

Traffic management on hill roads is one of the most critical areas of highway management. The objective is to ensure smooth, efficient, reliable, and safe traffic operations. Since traffic conditions, such as traffic demand and supply, hill road network, the density of population, terrain, weather condition, surrounding habitation, etc., are different from area to area, traffic management should be adequately designed for each targeted section. The success of traffic management has to be judged by affirmative answers to the following questions, whether:

1) Road users are kept informed of a route, traffic, and weather conditions and given clear guidance;
2) Undesirable conditions (incidents, accidents, bad weathers, congestions, delays, lane closures, etc.) affecting vehicle movement are mitigated and managed efficiently;
3) Emergencies are responded to and handled quickly;
4) The system extends help and assistance in case of need and that such help is extended quickly when asked for;
5) Traffic laws are complied with by vehicles and road users;

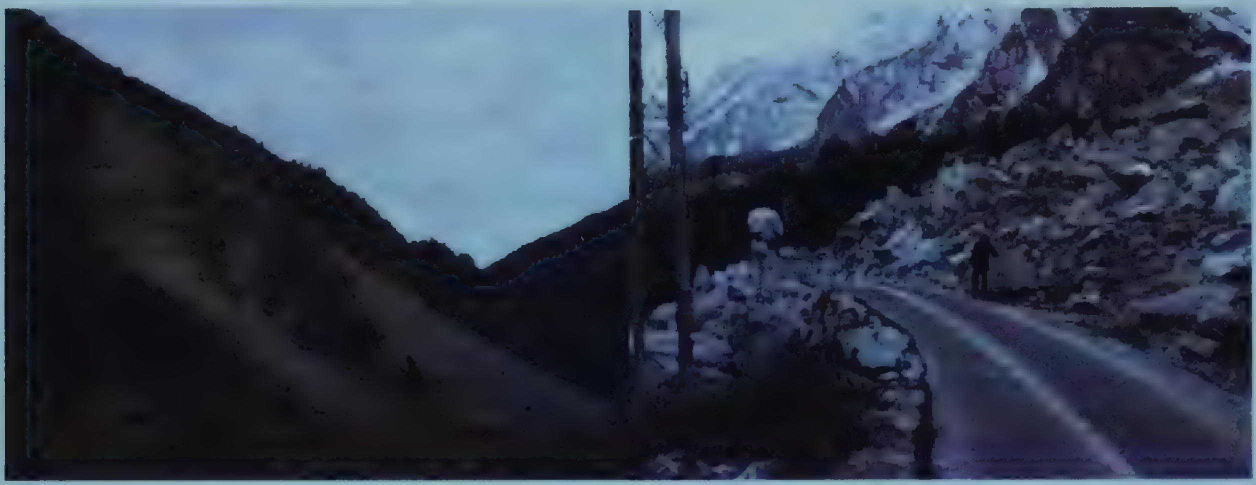
A traffic management system is backed by technology which can accomplish the tasks 1) to 5) above in general and more precisely, which can;

- ✓ detect, classify, and track the trajectory of any vehicle, detect violations and isolate vehicles involved in an accident or disabled vehicle;
- ✓ measure real-time weather conditions (wind speed, heavy rains, visibility) and traffic condition (speed, flow, etc.);
- ✓ support two-way communication between a road user and the "Traffic Management" authority, one-to-many communication between a road user and other traffic management and emergency services, and inter-team communication;
- ✓ display in real-time on Variable message sign (VMS) boards strategically on the route and portable VMS mounted at the back of tracks, broadcast on dedicated

radio about the information on the route, traffic and weather conditions, giving appropriate directions to the road users;

- ✓ The traffic management system has appropriate institutional arrangements providing for inter-agency agreements/understanding, protocols, and Standard Operating Procedures (SOPs) for routine and emergency interventions.

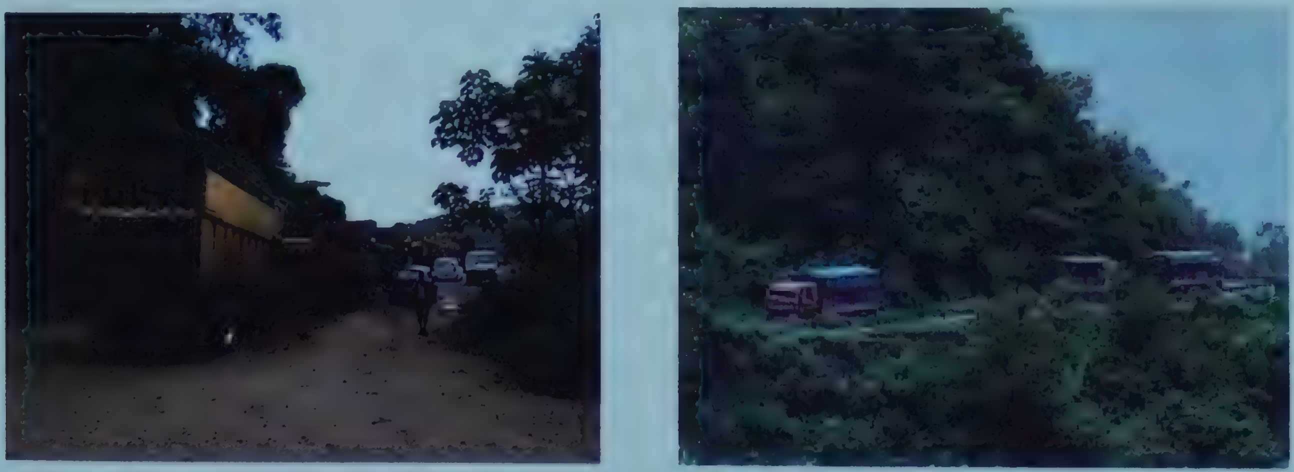
Hill roads are typically prone to disasters such as landslides, debris flow, slope failures, etc. mainly caused by rainfall. In India, rainfall during the rainy season, especially the monsoon season, has caused frequent damage to roadways especially in mountainous regions such as the northern region, northeast region, etc. Figure 2-1 shows typical road disasters on hill roads.



Source: JICA Expert Team

Figure 2-1: Road Disasters in the State of Uttarakhand (Left) and Sikkim (Right)

In light of freight transportation, large-sized vehicles become essential to support today's economy and social life, which is not an exception across mountainous regions as shown in Figure 2-2. On the other hand, overloaded/oversized vehicles which violate the "Motor Vehicles Act" are a major cause of damages and deteriorations on road structures as well as environmental problems such as air/noise pollution. In addition, it triggers traffic congestions toward the ~~up-hill~~ uphill section and serious traffic accidents toward the downhill section, posing threat to road safety on hill roads.

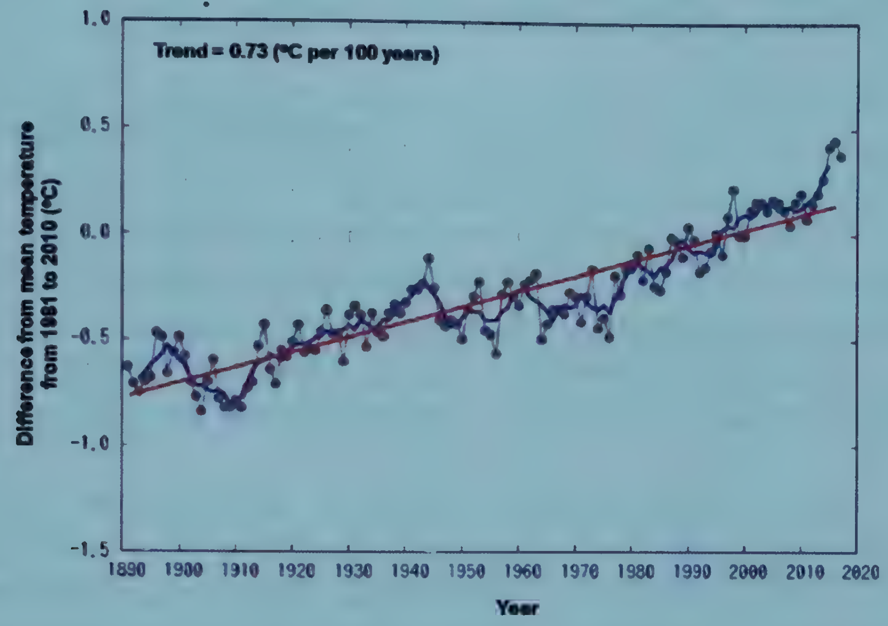


NH40 (Meghalaya) NH21 (Himachal Pradesh)

Source: JICA Expert team

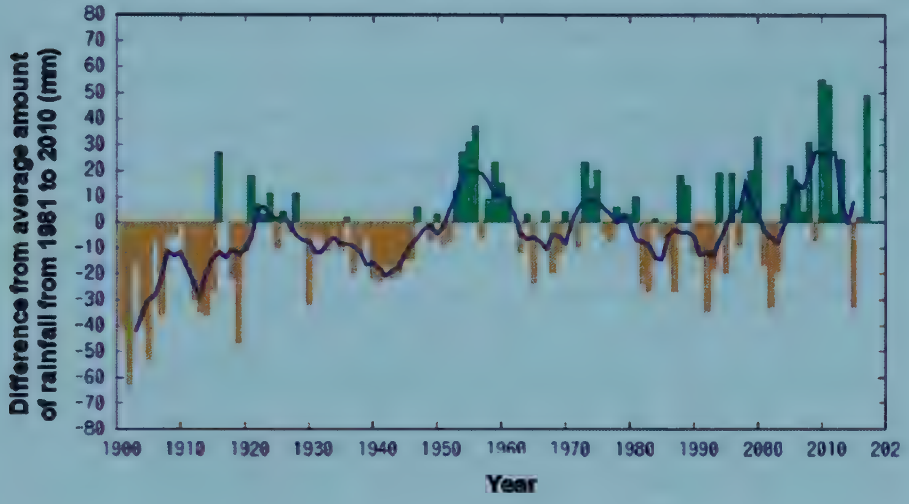
Figure 2-2: Oversized Vehicle Traffic in Mountainous Regions

From a perspective of global climate change, a higher risk is posed to hill roads. For example, the world's annual mean temperature has increased by approx. 0.73 °C every 100 years by repeating various changes. Especially, high temperature has been observed in most of the years since the mid-1990s (See Figure 2-3). The annual amount of rainfall in the world's inland area, on the other hand, is repeating periodic changes since records began in 1901, as shown in Figure 2-4. In the northern hemisphere, a larger amount of heavy rainfall was observed around in the 1920s, 1950s, and mid-2000. In the meanwhile, active monsoon or tropical depression/ cyclone has been reported to frequently cause heavy rainfall across South Asia to Mideast, including India.



[2]

Figure 2-3: Deviation of World Mean Temperature



[2]

Figure 2-4: Deviation of World's Annual Amount of Rainfall

It is a sad fact that thousands of people were killed by recent natural disasters, which include heavy rainfall between June and November in 2005 (India), heavy rainfall between June and August in 2007 (India, Nepal, and Bangladesh), cyclone in November 2007 (Bangladesh), heavy rainfall between July and September in 2010 (India, Pakistan, and Nepal) and heavy rainfall in June 2013 (India and Nepal). Especially, cyclone in November 2007 caused a catastrophic disaster, which killed more than 3,300 people and more than 800 missing people.

[2]

Taking account of the major characteristics of hill roads, this chapter of traffic management aims to present the following three major areas:

1) Traffic Management (in Section 2.4)
2) Early Warning System (in Section 2.5)
3) Overloaded Oversized Vehicles (in Section 2.6)

2.2 Objectives

In light of the background mentioned in the previous section, "Traffic Management" aims to support road users 1) ensuring smooth, efficient, reliable, and safe traffic, and 2) providing a comfortable driving environment, which is realized by road operators to grasp ever-changing road and traffic conditions, provide timely road traffic information to road users, and address abnormal situations.

Safe operation of hill roads would require that every road user follows traffic regulation (e.g. speed limit, size, or weight limitation) and his/her behavior does not endanger his/her own safety as well as the others. Traffic management shall, therefore, aim at compliance with the regulations and ensure safe driving behavior, particularly that caused by the force of circumstances (e.g. lack of awareness, anxiety, frustration, fatigue) on the highway by constantly informing, advising and through traffic control devices (e.g. static or variable signs, pavement markings, delineation, etc.) besides eliminating the causes of undesirable behaviors (e.g. delays due to incidents).

A comfortable driving environment can be achieved by road user-oriented traffic management. He/she needs to be offered conditions on highways that are conducive to smooth, efficient, and safe travel with as much comfort and convenience to the road users as possible, recognizing that a road user may be an anxious user, unfamiliar with the roadway, traffic and weather conditions, route to his/her destination. His/her anxiety level further rises if he/she encounters unfavorable travel conditions (e.g. bad weathers, incidents, accidents, congestions, vehicle breakdowns, non-availability of filling stations/user amenities close by). An anxious driver easily gets fatigued and prone to make mistakes (e.g. due to slowed down reflexes, lost directions, wrong or emergency maneuvers) and endanger his/her own safety as well as other users. In the event of an accident, a road user involved in an accident requires immediate help, and immediate clearance is necessary on the roadway to prevent secondary accidents and vehicle pile-ups. Traffic management has to take care of all these by gathering real-time information, making appropriate interventions (e.g., informing, guiding, and helping the road user, minimizing congestion, clearing incident sites) and reassuring the road users that the best-operating conditions under the given circumstances prevail on the highway with regard to smoothness, efficiency, and safety.

This is a multidisciplinary task, which can be accomplished only by (i) cross-organizational framework, (ii) monitoring-based technology, and (iii) real-time management intervention within the given legal framework. The detail ~~are~~ is mentioned in the subsection below:

2.2.1 Cross-organizational Framework

The organizational framework of traffic management requires the cooperation of and coordination with several agencies in their respective areas of jurisdiction (functional as well as geographical) with a focus on the road users. The road users are less concerned about the jurisdictional issues of the agencies and only want delivery of services in terms of smoothness, efficiency, and safety regardless of the agencies. The agencies, on the other hand, have jurisdictional limitations defined by laws. For example, emergency services (e.g. fire-fighting, ambulance) and the law-enforcing authorities (e.g. traffic police, transport authority), which are reactive but have an extremely important role, have little or no role in traffic management infrastructure and technology. Road administrator has a proactive role and has to anticipate all the problems that may arise, provide and maintain all infrastructure, make decisions on technology, and involve in real-time traffic operation issues, but has no law enforcing role.

Accordingly, the organizational framework for traffic management shall be based on the principles of close cooperation and coordination among agencies, preferably formalized in formal interagency agreements, with well-defined roles and responsibilities, operational protocols, and Standard Operating Procedures (SOPs).

2.2.2 Monitoring Based Technology

Another important aspect of traffic management is the technology, which arises out of the need to have real-time information on the roadway, traffic, emergencies, and weather conditions for the entire stretch of the highway. These conditions keep on changing spatially as well as temporally. It is essential for both road users and the Traffic Management authorities to be aware of these changes in real-time so that road users know what to expect during travel and authorities know how to intervene appropriately.

These changes can be captured by various types of 'intelligent' sensors (e.g. voice, image, vehicle presence and passage, speed, weight, heat) located at positions that can represent the conditions over the entire stretch of the highway. The sensors, which work on various technologies (e.g. audio, video, microwave, infrared, laser, electromagnetic induction, thermo couple, photo-electric), capture the real-time data. The data are logged into meaningful formats by the sensor electronics and controllers and sent to the center commando of highway traffic management (the Center) through a communication network, which in turn has many technology options (e.g. wired, wireless, mobile, cloud). The Center disseminates information through the communication system to road users and other relevant agencies. In this sense, data collection and dissemination technologies are vital in highway traffic management.

2.2.3 Real-Time Management Intervention

Traffic management intervention, controlled and coordinated by the Center, has to be in many forms, such as emergency intervention (e.g. guidance to the road user in distress, rushing rescue and relief), user-centric intervention (e.g. information and guidance on traffic, roadway, weather conditions, congestions, detours, closures, and diversions), instruction to various teams and agencies to intervene (e.g. patrolling team, maintenance team, emergency service, traffic management team, police authority, transport authority, trauma care service, roadway clearance team, housekeeping team), monitoring and evaluation of actions, course correction.

As already stated, SOPs for intervention have to be drawn up delineating the procedures for data handling and analysis, the processing algorithm, inter-agency information sharing, dissemination of information, prediction models, roles and responsibilities of agencies, intervention protocol including timing and nature of the intervention.

2.3 Strategy and Framework of Traffic Management on Hill Roads

2.3.1 Traffic Management Strategy

Traffic management strategy shall focus on the following:

1) Technology platform: A technology platform that can enable integration of various system components and ensure interoperability at vendor level, as well as systems level, shall be selected. This will require intra system and inter-system standardization.
2) Technology options: Many options are available for sensor (e.g. inductive loop, magnetometer, active and passive infrared and microwave, video image processing), communication (e.g. wired, wireless, dedicated short-range communication, cloud), and display technologies (e.g. variable message signs, radio broadcast, in-vehicle messages and displays on the on-board navigation system, mobile internet access). The appropriate technology option shall be selected after comparative studies in terms of cost, effectiveness, marketability, interoperability, and scalability of the technology, taking account of characteristics of targeted mountainous highways.
3) Processing algorithms: These have to be dealt with at two levels; first at the level of system electronics, which is internal to the technology (e.g. encoding sensor signals after detection, transmitting the coded data to the Center and decoding the data into meaningful output), and the second, at the level of Traffic Management System, which is external to and independent of the technology (e.g. converting the sensed data into speed, flow, density, headway). The two levels shall be compatible with each other.
4) Developing a Traffic Management System Policy framework: Detailed studies on 1) to 3), preferably by an experienced consultant, shall crystallize into the Traffic Management Policy framework, which shall form the basis of procurement of the system through competent systems and technology vendors.
5) Planning, creating, and installing Traffic Management infrastructure: All equipment, mountings, housings, display devices, communication lines, hardware, software, interfaces, peripherals, buildings (e.g. the Center), structures, repeaters/junctions, etc., shall be planned, procured, installed, tested and commissioned.
6) Institutional arrangements: All agencies other than road administrator involved in traffic management (e.g. police, transport authorities, road clearing service providers, ambulances, fire service, trauma care centers) shall be identified and agreements/understanding reached amongst them to follow an agreed set of protocols and SOPs for traffic management.
7) Developing protocols and SOPs: These shall define the roles and responsibilities of the agencies, the information flow mechanism, the manner of cooperation and coordination amongst them, the nature and timing of intervention, reporting requirements, performance evaluation, and course correction.

2.3.2 Framework

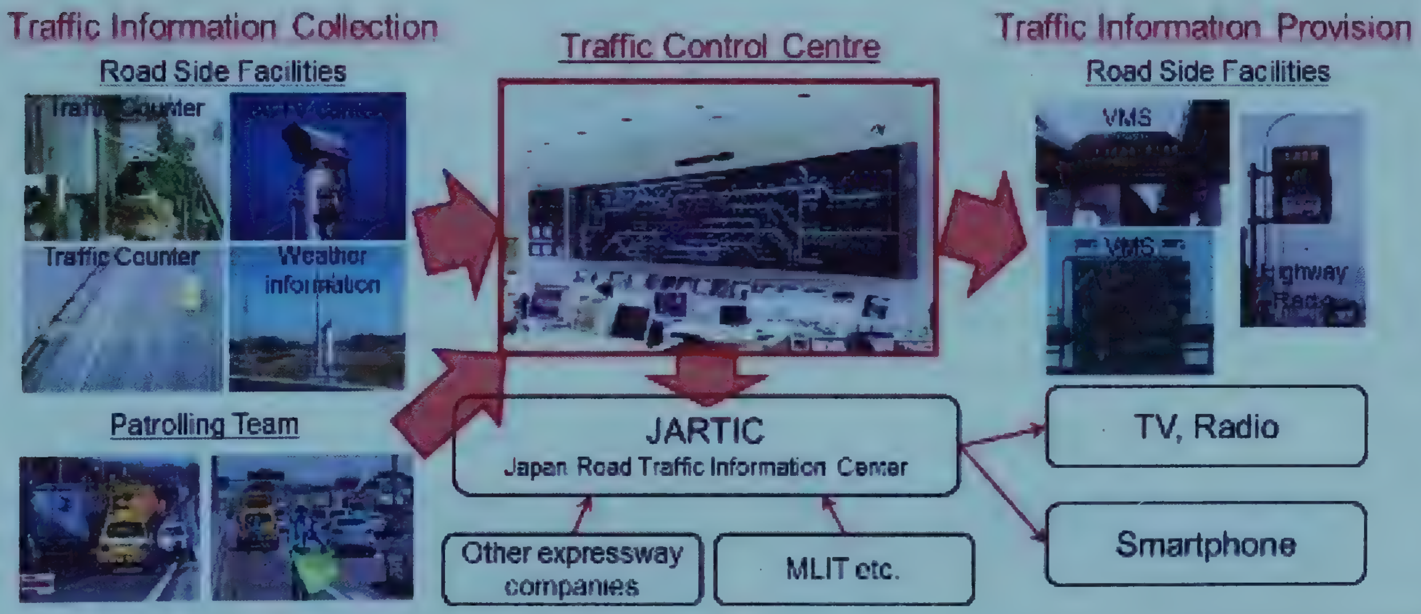
Traffic management is the application of traffic control measures through information collection on a real-time basis, processing the same i.e. collation and analysis and finally dissemination of the information to the users and concerned agencies, stakeholders, and security/legal/law and order administrators.

For safety, prime importance is placed to provide real-time and precise information to users on the highway. The entire system shall be based on a computerized Highway Traffic Management System (HTMS) incorporating Intelligent Transportation System (ITS).

A system working in 24x7 shall be established for informing road users of road conditions, traffic situations/incidents, and weather conditions on the highway and to make interventions as required for smooth, safe, and efficient traffic movement by providing rescue and relief to the road users to avoid distress.

The system primarily shall include;

- ✓ Acquisition of data from the various sources such as the road, the users, the maintenance and operation patrolling, the ambulance, and the intervention team.
- ✓ Three-way communication 1) between the data sources and the Center, 2) between the Center and the data sources and display units, and 3) between the maintenance and operation teams, through a transmission system.
- ✓ The Center collects, collates, and processes all data and control the highway operation. Data received is also archived for a set period of time.


Traffic Information Collection
Road Side Facilities
Traffic Counter
Traffic Counter
Weather information
Patrolling Team
Traffic Control Centre
JARTIC
Japan Road Traffic Information Center
Other expressway companies
MLIT etc.
Traffic Information Provision
Road Side Facilities
VMS
VMS
Highway Radio
TV, Radio
Smartphone

Source: JICA Expert team

Figure 2-5 : Traffic Management Framework

2.3.3 Information Collection

The information collected on highways for proper traffic management shall be divided into two components, which are (1) Patrolling and (2) ITS. Information collection shall consist of 1) Video Surveillance System (CCTV), 2) Video Incident Detection System (VIDS), 3) Emergency Communication System, 4) Meteorological Data System, 5) Weigh-in-Motion & Weigh Bridge System, 6) Automatic Traffic Counter cum Classifier (ATCC), 7) Mobile Radio Communication System and 8) Network / Communication Infrastructure.

(1) Patrolling

Routine patrolling and ad hoc patrolling is required to provide as necessary to assist road users with information feedback, and various alternative functions to be performed.

The members of the patrolling team shall be adequately trained in related traffic management aspects, road safety, and primary first aid. The purposes of these patrolling are to;

- ✓ provide the road users of the highway with basic mechanical help for vehicles that break down on the road and also protect other road users from such vehicles.
- ✓ identify quickly traffic hazards of whatever nature, such as unauthorized parking, public transport vehicles, debris, stray animals, crops, etc. The patrolling team takes the necessary measures to remove such obstructions.
- ✓ provide emergency management at accident scenes until such time as the appropriate authorities arrive.
- ✓ provide information to road users for the rest of the highway section (generally for 50km ahead or next exit whichever is closer).
- ✓ maintain daily records of assistances provided to road users.
- ✓ observe, record, and report suspicious aspects/objects on the highway, hazards, and incidental damage caused by vehicles, floods, storms, or any other random events, such that the highway maintenance records and database are continuously updated.

1) Patrolling Vehicle Equipment and Accessories

A suggested minimum provision may consist of the following:

- ✓ Vehicles capable of running mountainous highways in all-weather conditions, having 2 axles, 2 front seats, 2 back seats, sufficient rear space for equipment storage, fitted with rotating light and hooter, and painted with a unique color pattern for quick recognition, with the agency name and emblem painted prominently on sides, back and front, together with the center help line numbers. Vehicle equipment shall comprise parking, low beam, high beam, tail, brake, indicator, interior lights, rear and side-view mirrors, screen wipers, spare wheel, and reflector.
- ✓ Each vehicle shall carry Traffic Management Equipment, such as;
    - Sign boards: "Accident ahead" - 3 Nos, "Lane merging" - 3 Nos, "Direction Arrows" - 3 Nos, "Speed Limit (e.g. 80/60/40/20km/h)" - 3 Nos, "Keep left / right" - 2 Nos (e.g. all signs are 1200mm size).
    - Sign stand set (one for triangular, and the other for circular sign) - 6 Sets.
    - Flags, whistle, reflective hand signal.
    - Traffic cones (e.g. 500mm size) - At least 20 Nos or Flexible polythene water ballasted barriers - At least 5 Nos.
    - Barricades, tapes, stands, flags of such as 600 x 600mm made of good red cloth, secured to a 1m long staff. Paddles such as at least 600mm wide and provided with rigid handle with markings SLOW, STOP.
- ✓ Each vehicle shall also carry the following equipment;
    - Fire extinguisher - 1 Nos.
    - Gas cutter with protective glass.
    - Liquid container - 2 Nos, Water container with fresh water
    - Rubber gloves, Leather gloves - 1 pair each.
    - Brooms one hard bristle, other soft - 2 Nos.

- Gum boot - 4 Pairs, Rain coat - 4 Pairs, Blanket - 1 Nos.
- Torch lights - 4Nos., Spare batteries, Flashing light - 1 Nos.
- Hydraulic jack, Towing chain, Animal hook.
- Tool set (with a standard set of spanners, pliers, hammers, etc.).
- Digital Camera, Measuring tape.
- Paper pad, Forms, Pen / Pencils, Folders.
- First aid kit

✓ As a minimum, each patrolling vehicle shall carry sufficient communication equipment to render its passengers capable of direct communication with the Center.

2) Patrolling Staff

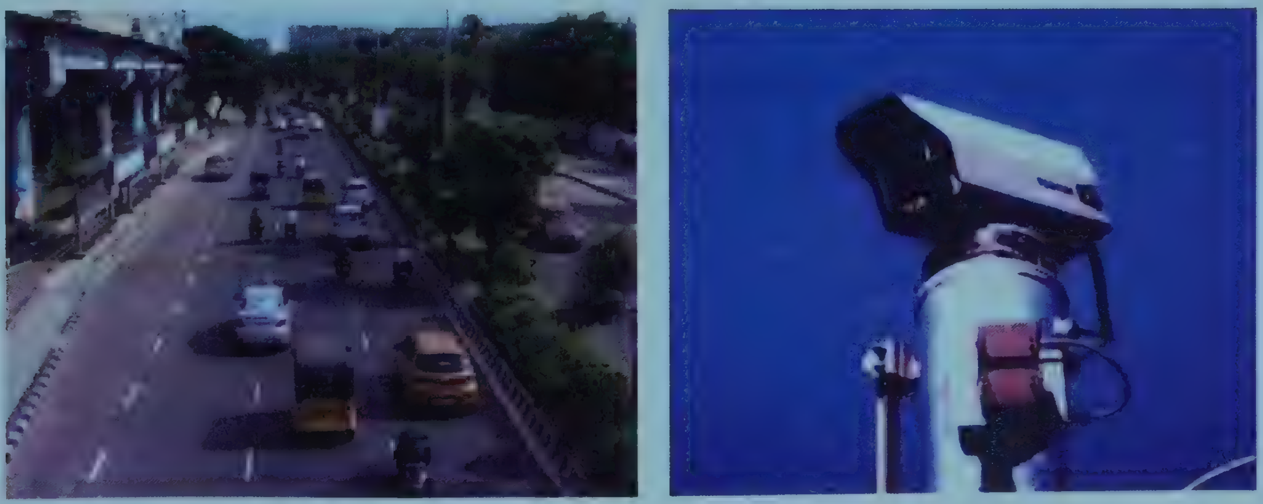
The team which is deployed with each patrolling vehicle needs adequate training for their tasks, especially in primary first aid, traffic management at the incident site, vehicle maintenance including minor repairs. There shall be sufficient manpower for each patrolling vehicle shift. Typical staffing pattern is;

- Route Patrol Officer
- Assistant Route Patrol Officer, with first aid training
- Lane Assistant
- Driver, with knowledge of vehicle repairs

(2) ITS (Intelligent Transport System) for Information Collection

1) Video Surveillance System (CCTV)

Closed Circuit Television (CCTV) shall be installed to monitor traffic flow, security aspects, vehicle detection and incidences on the highway section and related surrounding areas effectively as well as generate a tamperproof record for post-event analysis. presents the typical CCTV system.



View transmitted to the Center

Typical CCTV

Source: JICA Expert team

Figure 2-6 : Typical CCTV Information Transmission to the Center

The requirements and specifications of the CCTV system shall be referred to the "Chapter 3 - Video Surveillance System (CCTV) of Advanced Traffic Management System (ATMS) on NHs (Functional & Technical Specifications of ATMS Components / Sub-Components, NHAI, August 2016)".

2) Video Incident Detection System (VIDS)

The CCTV-based VIDS shall be used for automatic detection of incidents and generation of local visual alerts. It also includes the associated visual alerts in the form of flashing lights which are connected to and activated by the VIDS. The VIDS offered shall have the capability to operate in low light conditions normally experienced during the night. In very poor visibility conditions such as during winter fog/smog, the VDIS shall detect the condition of poor visibility and generate visual alerts. Further, it shall raise an alarm if signal/image quality is too poor to reliably process.

The VIDS, essentially consisting of a fixed CCTV camera and an attached (& co-located) Video Image processing unit, shall perform remote incident detection at designated spots on the highway section and immediately provide local warning to nearby travelers/road users on detection of relevant incidents. It shall also communicate such detected incidents to the Center for storage, analysis & reporting.

The requirements and specifications of the VIDS shall be referred to the “Chapter 4 - Video Incident Detection System (VDIS) - CCTV Based Video Analytics of Advanced Traffic Management System (ATMS) on NHs (Functional & Technical Specifications of ATMS Components / Sub-Components, NHAI, August 2016)”.

3) Emergency Communication System

Emergency communication system with loud speaker, micro phone, activation button with LED, indicating conversation is on, shall be housed in a vandal-proof casing and operate in full to play mode in the noise level of up to 95dB with in-built diagnostic features for automatic detection in case of damage by any object.

The emergency communication system may comprise the mobile radio base stations and the Center equipment as well as the Emergency Call Boxes (ECBs). The term “Emergency Roadside Telephone” or the term “Phone” covers the phone instrument, mounting hardware, pole, or any other mounting structure along with grouting, the charging stations, secondary power source such as the batteries, and the solar modules in case the units are solar charged.

The ECBs are free of charge and may be of dialing for push-button type and are meant for the notification of emergencies such as accidents and/or other emergency situations on the highway requiring immediate help/intervention. The ECBs are not connected with any other ordinary telephones and these shall be noticeably posted above the dialing system or the push button. However, it shall have provision for connecting to mounted mobile set on ambulances, towing, and patrolling vehicles. The emergency communication system shall have the facility to connect mobile to mobile, mobile to a controller, and controller to mobile along with the systems for waiting, holding, and transfer of calls. The system shall use a pair of frequencies to be allotted for the purpose by the Department of Telecommunications.

ECBs shall be installed in tunnels and other locations where mobile network is not available, such as remote local areas. In a location where a mobile network is available, on the other hand, an approach is to utilize “24/7 Unique Toll-Free Helpline 1033 for road users” instead of installation of ECBs.

The requirements and specifications of the emergency communication system shall be referred to the “Chapter 6 - Emergency Roadside Telephone System of Advanced Traffic

Management System (ATMS) on NHs (Functional & Technical Specifications of ATMS Components / Sub-Components, NHAI, August 2016)".

4) Meteorological Data System

Meteorological Data System shall comprise rain gauge, thermocouple/pyrometer, humidity meter, anemometer, visibility meter, and a sensor for measuring pavement surface temperature. They shall be installed on a single pole with a specific attachment and power supply fed from the integrator. They shall have the facility to communicate on Polythene Insulated Jelly Filled Copper Cables (PIJF) / Optical Fiber Cable (OFC). These instrumentation systems shall be placed at strategic locations or at places where the weather is likely to change. Since highways in mountainous areas are susceptible to weather change than that in plain areas due to the nature of the terrain, planning of system arrangement should be meticulously performed.

The requirements and specifications of the meteorological data system shall be referred to the "Chapter 9 - Meteorological Data System (MET) of Advanced Traffic Management System (ATMS) on NHs (Functional & Technical Specifications of ATMS Components / Sub-Components, NHAI, August 2016)".

5) Weigh-in-Motion & Weigh Bridge System

Weigh-in-Motion (WIM) and Weigh Bridge system shall be installed for the purpose of control of illegal overloaded vehicles. The WIM system shall be installed as stipulated by IRC:SP:84, IRC:SP:87, and "the guideline for the control of over-sized / over-loaded vehicles (MoRTH, June 2020)". Section2.6 of this guideline serves as supplemental to the existing guidelines.

6) Automatic Traffic Counter cum Classifier (ATCC)

Automatic Traffic Counters cum Classifier system (ATCC) shall be capable of detecting and recording all categories of vehicles plying on the highway based on their speed, length, and a number of axles. These shall desirably be located near the toll plaza and the entry and exit locations on the highway. Considering the purpose of this system, ATCC is recommended to be installed on mountainous highways with high traffic volume, as mentioned in Chapter 2.3.6.

The system shall be robust and capable of operating with minimum maintenance and may be either piezo-electric or infrared. It shall have a minimum accuracy level of 99%. The logic units shall be microprocessor-based. The system shall be able to record and store vehicle data for a period of at least two weeks with a Daily Traffic Volume of up to 100,000 vehicles. The system shall have compatibility to transfer the data on PIJF/OFC by using any of the available communication modes like landline modem, GSM (Global System for Mobile Communications), CDMA (Code Division Multiple Access) depending upon the effective and economic operation of the particular mode available at the site. The system may be electric/solar power operated depending upon the availability of the source.

The requirements and specifications of the ATCC shall be referred to the "Chapter 10 - Automatic Traffic Counter-cum-Classifier of Advanced Traffic Management System (ATMS) on NHs (Functional & Technical Specifications of ATMS Components / Sub-Components, NHAI, August 2016)".

7) Mobile Radio Communication System

The Mobile Radio Communication system shall be capable of providing wireless communication between the Center and operation vehicles which mount units & handheld units for emergency response as well as routine O/M activities for the Highway.

The mobile radio communication system shall have vehicle-mounted units fitted on ambulances, cranes, and patrolling vehicles for facilitating instant communication even when these are on the move across the highway. Handled radio units shall be required for maintenance activities on the highway. The vehicle-mounted & handheld units shall communicate with the Center as well as amongst themselves. The Center besides having base/repeater stations and control equipment shall have a provision for a voice logger to be attached with it for recording all communications.

This system is preferably developed in a section where ordinary mobile service is not available or not stable (blackspot of mobile service) to secure reliable communication between officers in the Center and on operation vehicles in order to provide appropriate traffic patrol.

The requirements and specifications of the mobile radio communication system shall be referred to the "Chapter 11 - Mobile Radio Communication System of Advanced Traffic Management System (ATMS) on NHs (Functional & Technical Specifications of ATMS Components / Sub-Components, NHAI, August 2016)".

2.3.4 Center Commando of Traffic Management

(1) Traffic Control Center (TCC)

Traffic Control Center (TCC) is designed for round-the-clock operations of monitoring, online information acquisition, and processing the same for decision making. The Main Control Center has equipment of central computer, call center, terminal junction box, uninterrupted power supply (UPS), console, operator with monitors and joy sticks, rack accommodation, large display board, line printer and general-purpose office computer with monitor, printer, fax, and telephone. The system has a Network Management System (NMS) or real-time monitoring of Emergency Call Boxes (ECBs) and related network diagnostics.

The TCC is the repository of all the data acquired from the field and their processing, storing, and archiving. All the information for real-time monitoring of the highways is generated at the TCC and the relevant information is disseminated to the road users for appropriate intervention. Another important function is the operation management of the TCC itself along with its various sub systems.

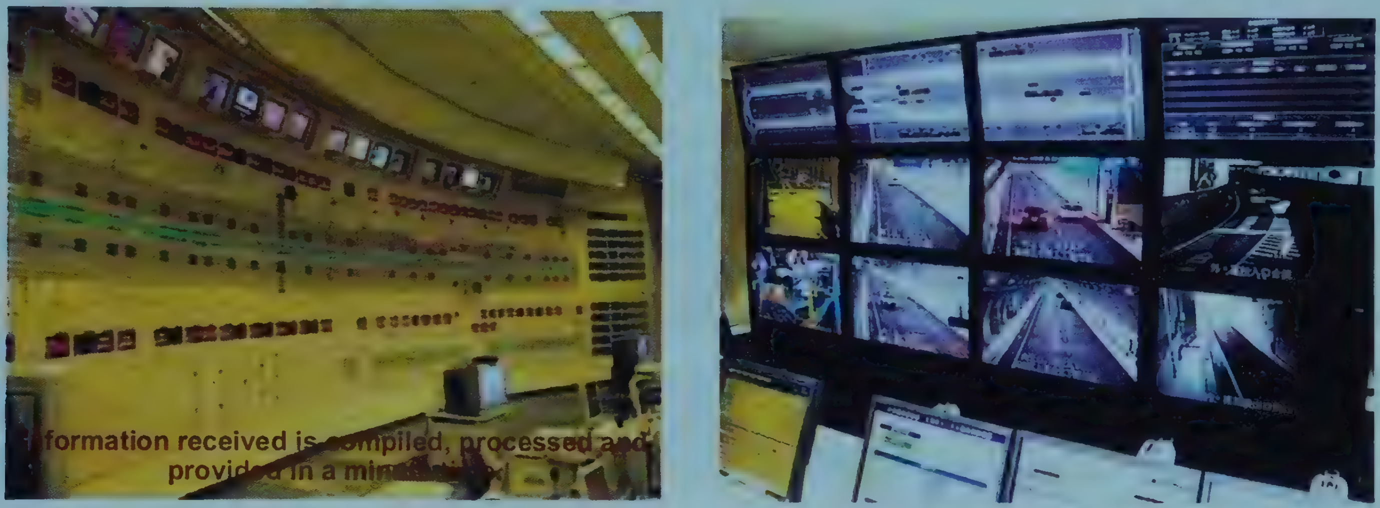
__Central Control Room (CCR)__: Typical equipment, hardware, and software are as follows;

- ✓ A central computer server with integrated ATMS and ATMS software.
- ✓ A traffic manager's terminal for the operation of the integrated ATMS.
- ✓ Call system equipment comprising operator's PC along with sub-systems and digital voice recorder.
    - Mobile radio terminal comprising operator's PC and engineering terminal.
    - Computers for Network Management System (NMS) for fiber optic communication system, CCTV console equipment.
- ✓ CCTV console equipment.

- ✓ Computers for VMS and Traffic Control.
- ✓ A large-size display screen.
- ✓ A line printer.
- ✓ An office computer.
- ✓ Power back up system (uninterrupted power supply (UPS))

Figure 2-7 presents a typical Traffic Control Center (TCC) and a close view of the monitoring screen.

The requirements and specifications of the TCC shall be referred to the "Chapter 14 - ATMS Control Centre with ATMS Software of Advanced Traffic Management System (ATMS) on NHs (Functional & Technical Specifications of ATMS Components / Sub-Components, NHAI, August 2016)".



Traffic Control Center

Monitoring Screen

Source: JICA Expert team

Figure 2-7: Images of Typical Traffic Control Center (TCC)

(2) Facility Control Center

Facility Control Center (FCC) is the nucleus of the system, which operates all facilities on highways. It monitors all facilities and supervises for appropriate functioning on a "24hour x 7day" basis. A modern FCC has a centralized configuration which broadly comprises of 1) Central monitoring and controlling equipment and 2) Transmitter sending messages to various terminals. The essential elements in the terminals are as follows;

- ✓ Power reception / distribution equipment
- ✓ Power generator
- ✓ Lighting facilities
- ✓ Emergency facilities
- ✓ Ventilation provisions
- ✓ Mobile communication facilities
- ✓ Water supply/drainage systems
- ✓ Information boards (including VMS)
- ✓ Meteorological equipment

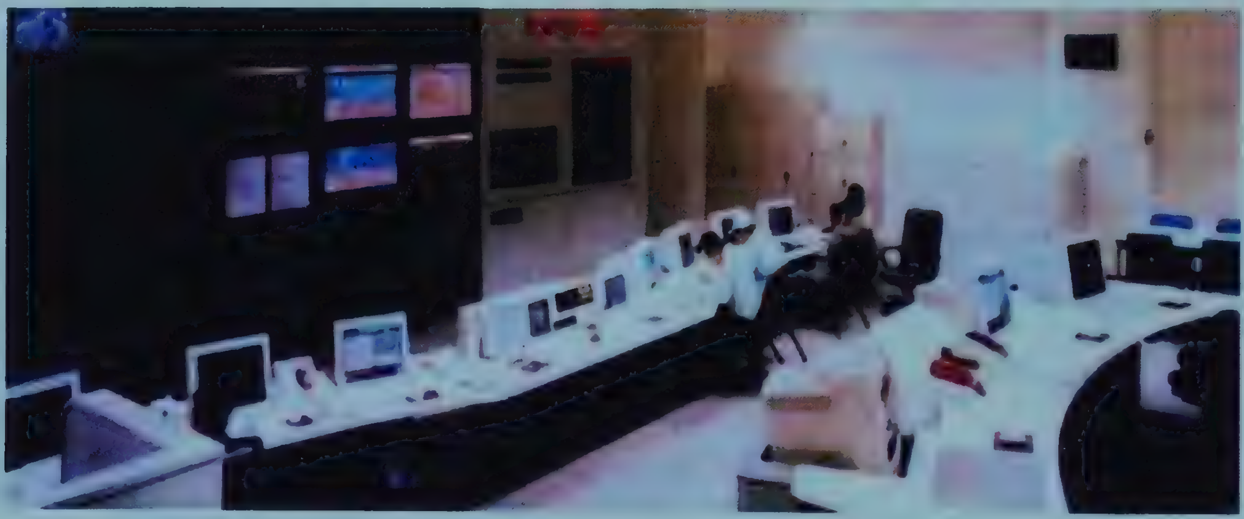
The FCC broadly consists of three components;

- ✓ A set of control desk of a large display monitor/control desk,

- ✓ A data statistics desk, and
- ✓ A simulator desk

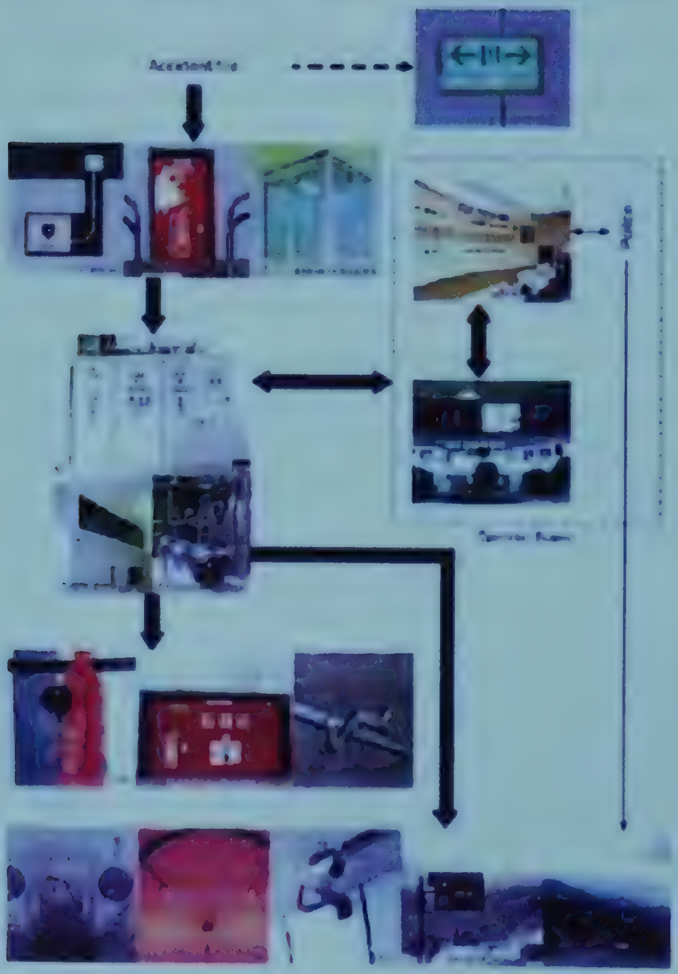
The above system collects, collates, and analyzes data collected from the data sources, and transmitting equipment exchanges information with various terminals located at interchanges, tunnels and important structures on mountainous highways. In order to increase the efficiency in processing and analyzing the huge database it would be necessary to have dedicated software development with inbuilt provisions to disseminate guide information in an emergency situation. Engineers and operators, on the site, shall have a mobile terminal for direct connection to the FCC. This provides support to the engineers to carry out the maintenance and inspection of road facilities.

Figure 2-8 and Figure 2-9 present typical Facility Control Center and Operations.



[3]

Figure 2-8: Image of Facility Control Center (FCC)

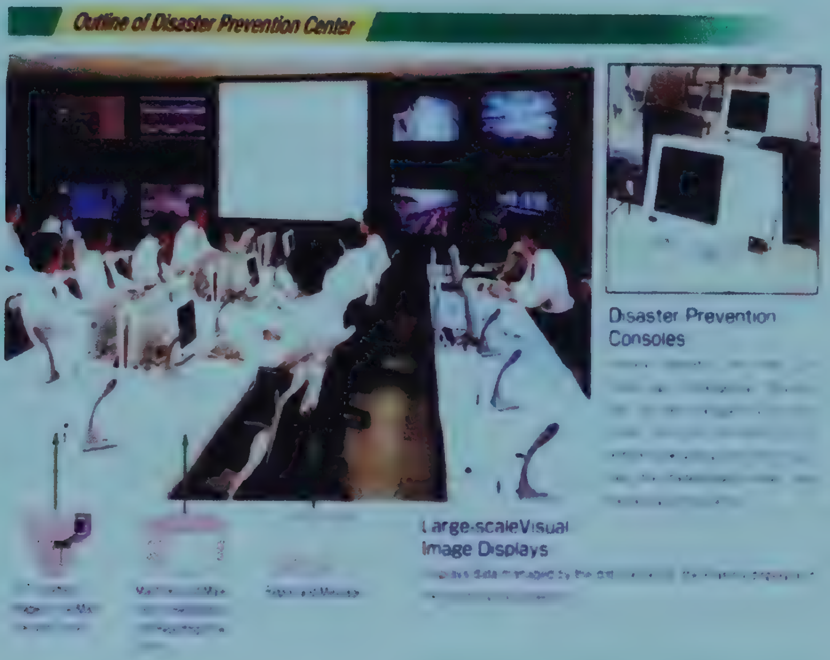


[3]

Figure 2-9: Typical Operations in Facility Control Center (FCC)

(3) Disaster Prevention Center

Disaster Prevention Center (DPC) is primarily engaged in disaster planning, prevention, preparedness, response, and recovery. All these fall into the category of emergency management. An emergency is defined as any unplanned event that can cause fatalities or significant injuries to employees, customers, or the public, or that can shut down businesses, disrupt ·operations, cause potential environmental damage or threaten a facility's financial standing. Emergency management is the process of preparing for mitigating, responding to, and recovering from an emergency. Figure 2-10 presents typical DPC in Japan.


Outline of Disaster Prevention Center
Disaster Prevention Consoles
Large-scale Visual Image Displays

[3]

Figure 2-10: Disaster Prevention Center

Typical disasters may occur/happen on mountainous highways and the cause of them are as follows;

Heavy Rainfall: This may cause the erosion of cut slopes/embankment, damage to the drainage structures (including bridges), and landslides. This is one of the most critical factors to lead to disasters on mountainous highways.

Cyclone: A cyclone is a tropical weather system with strong winds that have reached a sustained speed of 120 kph or more. The combination of growing population and development in not only coastal regions but also mountainous regions, changing climatic trends have increased the potential for loss of life and property in mountainous regions of the country.

Flood: Most states in India experience some kind of flooding after rains, heavy thunderstorms. Floods can be slow, or fast-rising, but generally develop over a period of days, the exceptions being "flash floods" (which result from intense storms dropping large amounts of rain within a brief period, and can occur with little or no warning), and dam/barrage failures (which can suddenly let lose a gigantic quantity of water).

Earthquake: An earthquake is a sudden, rapid shaking of the earth caused by the tectonic movement of the earth crust. This shaking can cause buildings and bridges / elevated highways to collapse, and sometimes trigger landslides and avalanches, all impacting the transportation network.

Wild land Fires: As residential areas expand into relatively untouched wild lands, people living in these communities are increasingly threatened by forest fires. Unpredictable wildfires can wipe out huge sections of landscape and endanger the lives of residents, necessitating evacuations from the threatened locations. Additionally, the smoke from these fires can significantly reduce visibility over a wide area, resulting in traffic disturbance, such as highway closures and traffic diversions.

Homeland Security: Terrorist attacks have become frequently occurring unfortunate events that exact a terrible toll on the country and fundamentally ~~affects~~ affect the way of life. Surface transportation is also changed~~,~~ and continues to change in response to the attack.

(4) Data Transmission System

Data Transmission System consists of a backbone optical fiber transmission system, cable system, interface system, network management system, repeater/ amplification system, and power supply system. There are three or four sub-centers (as appropriate) housing all the interface equipment apart from the Center, provided with, as appropriate, cables, interface, terminals. The cables from ECBs, VMS, meteorological data systems, ATCC shall be all Polythene Insulated on Jelly Filled (PIJF) copper cables and those from CCTV cameras shall be coaxial cables. Repeaters/amplifiers are used to maintain the quality of signals. All the cables have at least 20% spare capacity to allow for future expansion. The interface system shall be capable of handling the composite audio, video, and data signals at various interface levels and processing them.

2.3.5 Information Dissemination

Information collected and analyzed at the TCC shall be disseminated in the following manner;

To road users: By displays on Variable Message Signs on highways, Tunnel Warning Display Boards, Emergency Broadcast in Tunnels, Telephone Services, via internet web pages.

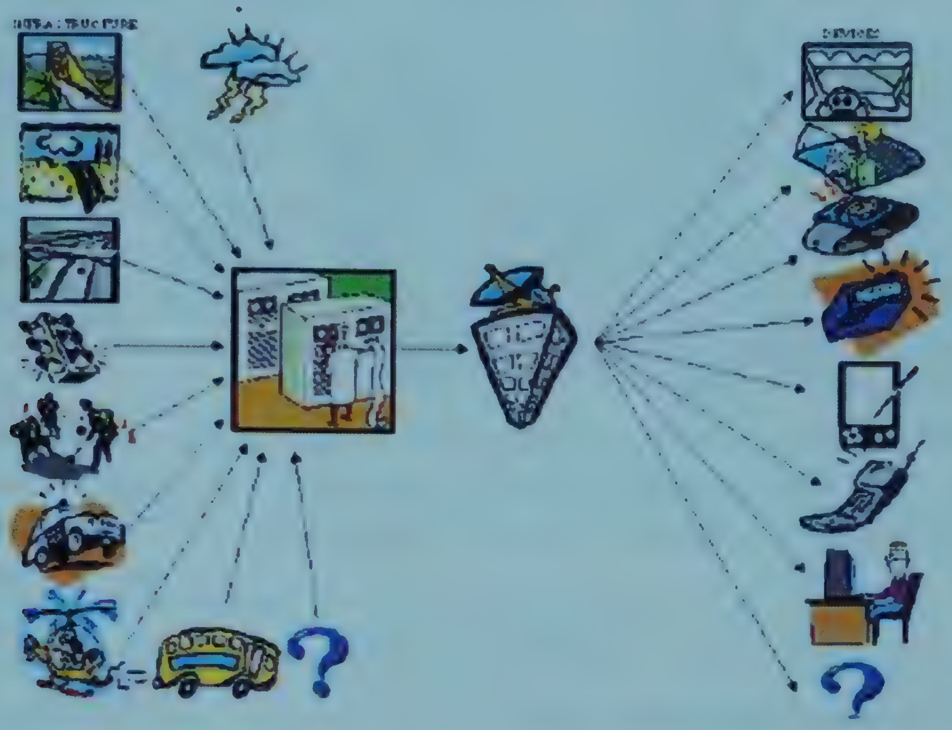
To operation and maintenance teams: By mobile radio communication system / mobile phones.

To ambulances: By mobile radio communication system / mobile phones.

To trauma centers: Via ambulances.

To law and order administrators: By mobile radio communication system / mobile phones.

Effective dissemination of user information services supports many types of information requests and categories of road users and combines multi-modal information in an effective and timely manner. Information may be provided in a number of ways, including static information and real-time information. Static information comes from such sources as transit schedules, planned work zones, and known road closures. Real-time information comes from a variety of sources including roadway-based sensors, surveillance equipment, patrol team, and also road users. The information assists road users in selecting a route, and departure times, mode of travel (if available) - both pre-trip and enroute. Figure 2-11 illustrates the possibilities of the range of data sources, processing, and uses of user information. The figure depicts various sources of data (on the left-hand side, and including highway conditions) which are collected and centrally processed (on the central part of the figure) to yield integrated information about the current and future travel conditions, and which are broadcast or disseminated to road users, allowing them to make informed choices about when, where and how to travel.



[4]

Figure 2-11: Sources and Uses of User Information

The information process extends well beyond the boundary of highways, both in terms of where the information is obtained and how it is distributed. Information on highway conditions and the dissemination of that information to road users shall therefore be viewed as part of a broader, region-wide, and Advanced Traffic Information System (ATIS). The subsections below from (1) to (6) explain the detail of each technology.

(1) Variable Message Signs (VMS)

Variable Message Signs (VMS) are very useful in conveying traffic information ahead to the drivers on real-time basis. VMS is capable of displaying several messages in a sequence and can be repeated. Such messages can be changed manually, by remote control, or by automatic control. VMS shall display pertinent traffic operation and guidance information only and not any advertising. Various situations where VMS would be appropriate are as below;

- ✓ Incident signs as accidents, traffic diversions due to such as landslides, incident management, monitor road works (men at work), adverse weather and road conditions, and operation with lane control signals.
- ✓ Traveler information such as display of road construction activity in near future, messages for testing of the system, and special events that affect the traffic flow.
- ✓ Public service announcements like messages relating to driver safety campaigns.

The requirements and specifications of the VMS shall be referred to the following and “Chapter 7 - Variable Message Sign (VMS) of Advanced Traffic Management System (ATMS) on NHs (Functional & Technical Specifications of ATMS Components / Sub-Components, NHAI, August 2016)”.

1) Locations of VMS

VMS is used to visually provide highway users with information about traffic, required time, road and weather conditions, etc. in order to ensure safe and smooth traffic. VMS is categorized and summarized in Table 2-1 as shown below.

Table 2-1: Locations of VMSs

Information Provision Device	Overview	Location
Highway information boards	Road closure and other information about serious impediments to traffic are provided over wide areas	- At a major junction of the highway network - At an entrance to a landslide-prone section or mountainous section
Tunnel entrance information boards	Basically for emergencies for those who use the tunnel.	- Refer to Chapter 7.5.1, Report and Alert Facility for Tunnel Operation
In-tunnel information boards	Basically for emergencies for those who use the tunnel.	- Refer to Chapter 7.5.1, Report and Alert Facility for Tunnel Operation
Weather information boards	Basically for weather information use.	- Installed where weather conditions are harsh or change abruptly.

Source: JICA Expert team

2) Technical Requirements

The system shall use Light Emitting Diodes (LEDs) / High Gain Trans-reflective Liquid Crystal Displays (LCDs) for outdoor ambient sunlight. Design and provision of VMSs shall be carefully considered, including the following points;

- ✓ Collection of preliminary data i.e. intended purpose, type of information to be displayed, and alternative diversion routes available.
- ✓ Type of VMS i.e. intended purpose, information to be displayed and technology to be used.
- ✓ Visibility in all weather conditions including foggy and misty conditions.

3) Placement of VMS

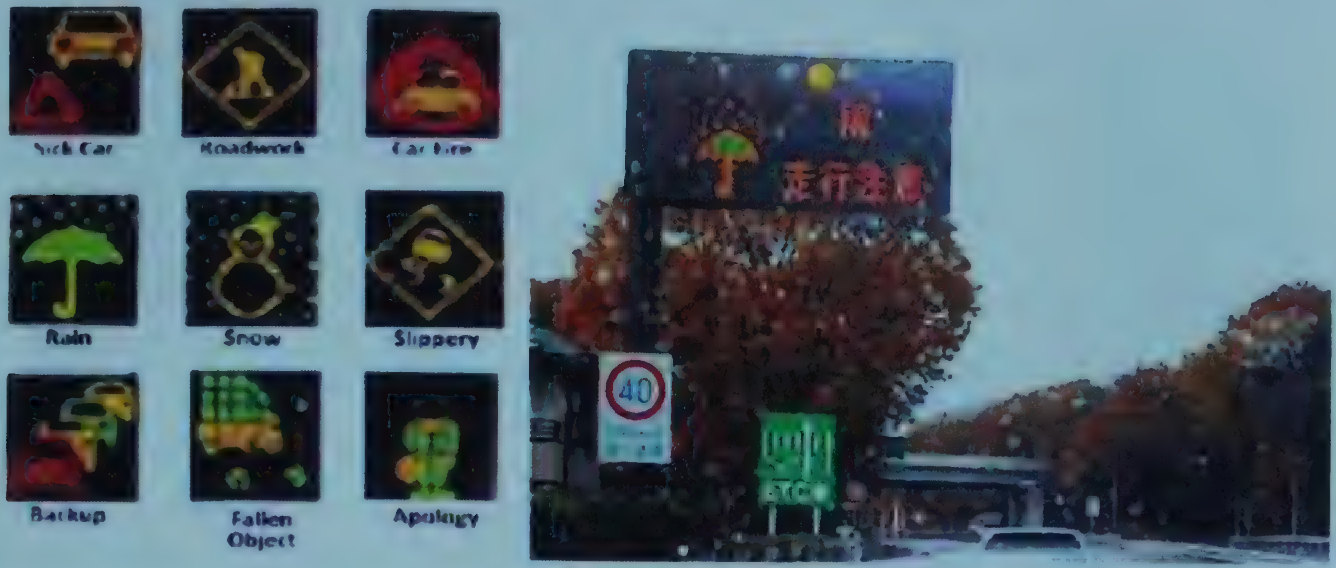
Placement of VMS shall be as below;

- ✓ Fixed VMS shall be mounted on a sturdy and aesthetically pleasing gantry structure whereby vertical clearance is available from the road surface. Safety barriers shall be provided at gantry support column(s) for the protection of the column and the safety of road users.
- ✓ The signs shall be visible from a distance of 300m. It shall not be located on curvature and a highway section having a grade exceeding 4%.
- ✓ Location and source of power along the road segment if it is not solar power.

4) Typical Pictorial Presentations

Some typical examples of pictorial presentations used in VMSs in Japan are presented in Figure 2-12 below, along with events and traffic flow situations.

Pictorial Presentation in VMS



Source: JICA Expert team

Figure 2-12: Pictorial Presentation in VMS

Events

Table 2-2: Events

Items	Events
Weather	Earthquake, Fog, Rain, Snow, Gust, Heat
Road surface	Wet, Flood, Freeze, Snow, Fallen object, Pot hole
Traffic	Accident, Repair work, Roadwork, Congestion, Travel time, Car fire
Wayside	Wave, Slope failure, Landslide, Shoulder damage, Fallen rock, Debris, Pyroclastic flow
Amenity	Occupancy, Services
Warning	Congestion forecast, Roadwork schedule

Source: JICA Expert team

Location of Events

Table 2-3: Location of Events

Items	Events
Location	Near "A Tunnel, "B Tunnel"
Name of interchange, if any	"Interchange A" – "Interchange B", at "Interchange A"
Distance	Ahead, 1km ahead
Route	"A Road", "B Road"

Source: JICA Expert team

Instruction Message

Table 2-4: Instruction Messages

Items	Events
Message	Road closure, No entry, Exit here (if access-controlled highway)
Speed limit	80kph / 50kph
Lane usage	Divert to right, divert to left
Warning	Caution, Slow down
Lifting	Removal finished

Source: JICA Expert team

Dissemination Location

- ✓ Upstream of the location where an event occurred

if access-controlled highway,

- ✓ In front of interchange prior to event location
- ✓ At entry interchange to a highway where an event occurred

Information Renewal Cycle

- ✓ Traffic condition: 1 to 5mins
- ✓ Weather condition: 10 mins
- ✓ Warning: Half-day or longer

The location of events differs according to their importance and requirements. In case of traffic accidents, the location of events is a point on the highway, which may be on a stretch of highway or as a region. For example, congestion is on a stretch whereas the meteorological information is applicable for the region.

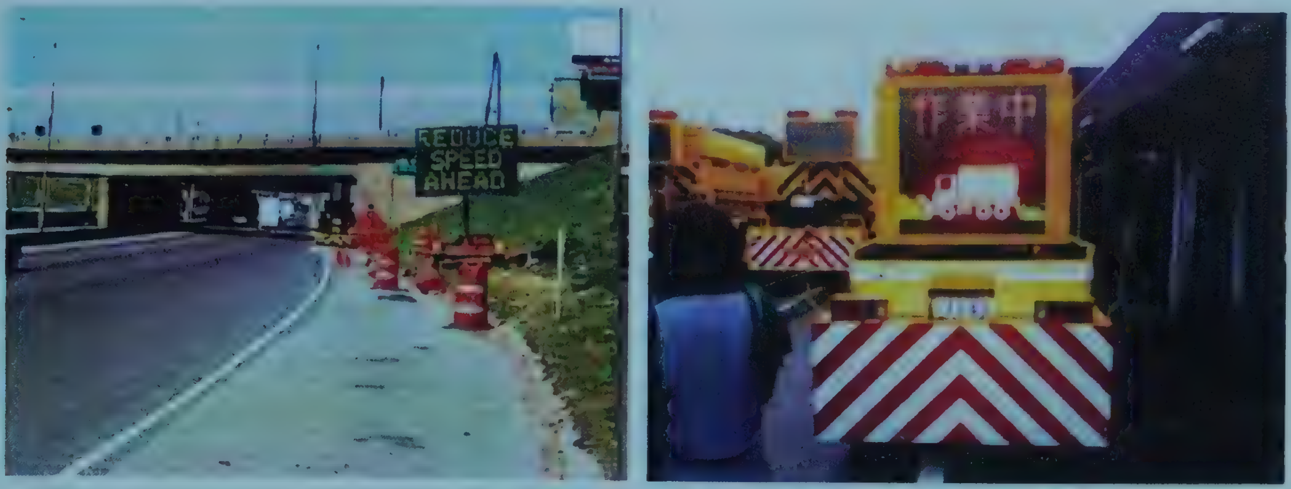
When a large-scale accident or incident blocking a highway happens, it is required to inform oncoming vehicles to avoid driving up the highway, use an alternative route, or exit at the next interchange in case of an access-controlled highway. When the number of lanes is reduced due to road work, it is necessary to instruct road users to slow down. The different instruction messages, according to the extent and seriousness of the event, shall be placed.

For appropriate actions by road users like slowing down or diverting roads shall be indicated before passing by major highway junctions or before a few interchanges enabling them to change the travel route or even commencing journey on the highway. Similarly, for lane closure due to road works, potable VMS(s), mentioned in the subsequent section, may be placed at or near the incident, where appropriate.

Information on traffic conditions shall be renewed on real-time basis may be at a cycle of 1 to 5 minutes, information on the weather - which does not change so quickly, can be renewed at the cycle of 10 minutes or so, and information on warning of scheduled work can be renewed on half-day or longer basis.

(2) Portable VMS - on Vehicles

VMS can be fixed or portable. Portable VMS can be mounted at the back of a truck or a similar vehicle. Portable VMS mounted on a truck could be powered by solar energy or battery, and show the sign of 'road closure', 'men at work', and/or speed limits in the construction zone. Proper placement of a portable VMS is critical to its effectiveness. The placement must give adequate time to motorists to react to the message and take necessary action. In the context of hill roads, portable VMS is recommended to be placed prior to a decision point with a couple of repetitions, as is the case with national highways in plain areas. It shall be provided adequate sight distance (around 300m) and shall not be interfered with by other traffic control devices. If portable VMS is set up along the roadway and a message is not to be required for a period of several hours, the sign panel is recommended to be turned away. Figure 2-13 shows a typical portable VMS.



Left: [4], Right: JICA Expert team

Figure 2-13: Portable VMS in Operation in a Work Zone

(3) Vehicle Actuated Speed Display

Radar Vehicle Actuated Speed Display complemented by a data-logging CCTV Camera shall be installed to be used as a sub-system of ATMS implementation. The speed display shall include mounting fixtures and the anchoring mechanisms for the same. These speed displays shall be installed to warn road users of overspeeding and thereby acting as a deterrent. They shall also have the capability to collect and relay real-time data for subsequent analysis in the Center.

The speed display shall provide textual or graphical warnings to the vehicles exceeding the preset speed limit, which is effective especially to regulate the speed of downhill vehicles. It shall further capture an image of the over-speeding (i.e. the speed exceeding the preset limit) vehicle.

Requirements and specifications of the vehicle actuated speed display system shall be referred to "Chapter 5 - Vehicle Actuated Speed Display of Advanced Traffic Management System (ATMS) on NHs (Functional & Technical Specifications of ATMS Components / Sub-Components, NHAI, August 2016)".

(4) Travel Time Estimation System (TTES)

Travel Time Estimation system (TTES) is installed to estimate the travel time over a highway segment between any two defined locations, especially if there are several alternative routes available and travel time varies depending on the day and time of the day. TTES employs RFID transceivers at such defined locations to identify vehicles by reading the RFID FASTag or any valid 18000-6C RFID tag (e.g. the OEM tags on many new vehicles) affixed on their windshields. Travel time estimation algorithm that executes on an exclusive server networked with the above transceivers, looks for the matching of tag numbers (the Tag-ID) read at the source (start location) of the segment with tag numbers read at the destination (end location of the segment. A statistical estimate of the travel time between two locations is arrived at based on the calculated time difference between the reads at these two locations for several matching tags).

The requirements and specifications of the vehicle actuated speed display system shall be referred to the "Chapter 12 - Travel Time Estimation System of Advanced Traffic Management System (ATMS) on NHs (Functional & Technical Specifications of ATMS Components / Sub-Components, NHAI, August 2016)".

(5) Highway Advisory Radio (HAR)

Highway Advisory Radio (HAR) is an effective means of providing road users with information in their vehicles. Traditionally, information is relayed to road users through AM radio receivers in their vehicles. Upstream of the HAR signal, road users are instructed to tune their vehicle radios to a specific frequency via roadside or overhead signs. Usually, the information is relayed to the road users by a pre-recorded message, although live messages can also be broadcast. For the application of the HAR system to a mountainous highway, it is necessary to allocate a certain frequency band for its purpose in close coordination with a relevant telecommunication agency.

Highway advisory radio (HAR) is an effective tool for providing timely traffic and travel condition information to the public. It has various advantages and disadvantages. It is the most important advantage that it can reach more users, or potential users, than VMS. While VMS reaches only those motorists at a particular point, and can only convey a short message, HAR has the advantage of communicating with any persons in their broadcast range. Further, the amount of information that can convey is much greater. Its primary disadvantage, on the other hand, is that it is restricted to low power, which frequently leads to poor signal quality (since it is affected by many factors outside, such as weather). In addition, it requires a driver to take an action (i.e., turn on vehicle radio and/or change the station manually). This can lead to a limited number of listeners of road users.

Messages are broadcasted in the field from transmitters by playing stored messages. These messages are transmitted to the field from a “central” location, which can either be the Center or any telephone. It only requires an analog phone line, not a central system, to the transmitter so that an operator can record a message in the transmitter to broadcast. This is labor-intensive if an agency maintains a number of transmitters, and traffic conditions change throughout the day. However, the advantage is focused on its inexpensiveness, and messages can be sent to a transmitter wherever a phone exists, even from a cell phone. Alternatively, a central message distribution system is used to record new messages, store pre-recorded messages, and distribute messages to the transmitters (simultaneous if necessary). This is a system typically based on a PC with security access control.

1) Deployment strategies

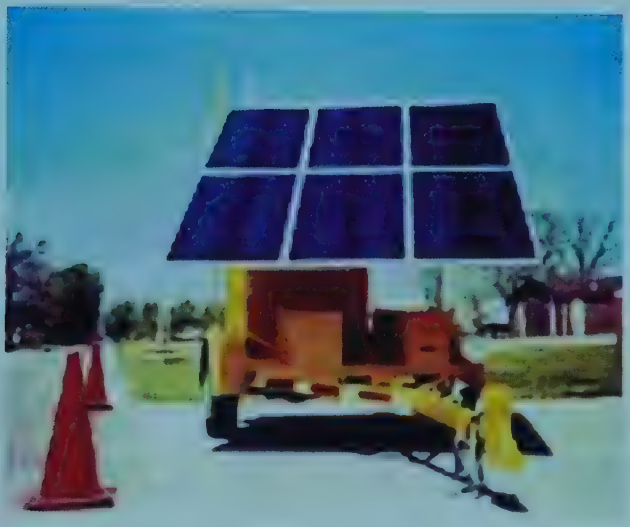
HAR can be broadcast in two ways: Point or Wide-Area coverage.

- ✓ In Point Broadcast, a single transmitter is used to broadcast over a given area. This is typically used at diversion points of the highway network. This type of implementation is popular with road users because the information is specific to them.
- ✓ Wide Area Broadcast transmits a signal to a larger coverage area using multiple synchronized transmitters. This is an effective strategy when a single message applies to a large coverage area, and the coverage area is sufficiently large for a road user to hear the longer message. The fact that a long single message, that is pertinent to specific road users for only a part of the message, is indeed a disadvantage.

2) Portable and Mobile Systems

Portable systems permanently installed on trailers as well as mobile systems installed on service or maintenance vehicles can be of value in providing timely dissemination of information to road users during short-term deviations from normal highway conditions.

This is particularly true in areas where there is a limitation, or no normal coverage or the permanent transmitter site has failed. These systems can be solar-powered, generator-powered, or battery-powered (See Figure 2-14). Portable / mobile systems can be set up at decision-making points where a route guidance system directs road users to an alternate route. This will increase the comfort level of road users by reinforcing their confidence that they are following the alternate route instructions correctly.



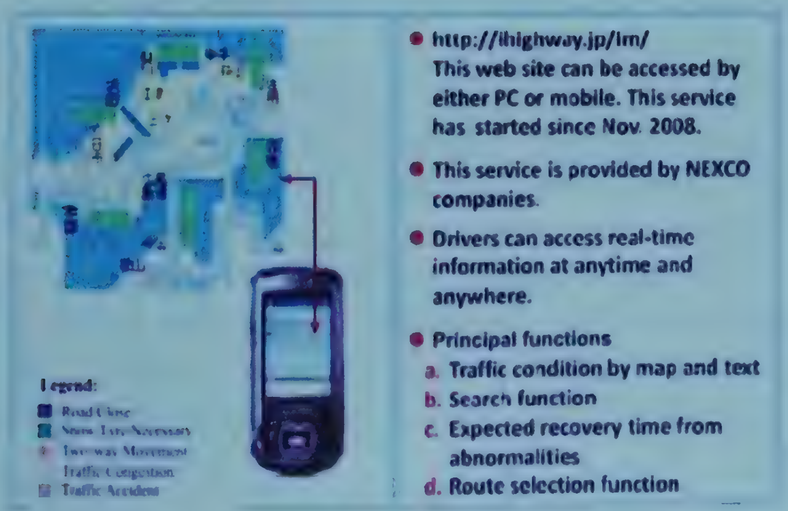
[4]

Figure 2-14: Portable Highway Advisory Radio Station

(6) Internet or Mobile Services (Reference)

On-line services to access the Internet represent an additional means to disseminate pre-trip user information. The effectiveness of the Internet as a fast and flexible communication medium has seen explosive growth in all sectors of society. The network is now in daily use by people in all professions. In Japan, several private Information Service Providers also have websites which provide similar information for multiple areas. Many of these sites broadcast;

- ✓ Real-time traffic flow information via color-coded maps
- ✓ Road closure information (e.g., for maintenance or natural disasters)
- ✓ Real-time video images (still captures or streaming video)
- ✓ Camera selection
- ✓ Travel advisory information for route planning
- ✓ Links to other websites
- ✓ News and weather



- http://ihighway.jp/im/
  This web site can be accessed by either PC or mobile. This service has started since Nov. 2008.
- This service is provided by NEXCO companies.
- Drivers can access real-time information at anytime and anywhere.
- Principal functions
  a. Traffic condition by map and text
  b. Search function
  c. Expected recovery time from abnormalities
  d. Route selection function

Source: JICA Expert team

Figure 2-15: User Information Showed in Mobile Phone

2.3.6 Arrangement of ITS Devices / System

(1) Arrangement of ITS Devices / System

"Appendix A - Guidelines / Rationale for Locating - ATMS Device / System of Advanced Traffic Management System (ATMS) on NHs (Functional & Technical Specifications of ATMS Components /· Sub-Components, NHAI, August 2016)" can be referred for the arrangement of ATMS devices /system, including location and interval. Nevertheless, the arrangement needs to be meticulously studied and planned in the context of a concerned hill road.

(2) Limitation and adaptation of ATMS to Mountainous Highways

On highways in mountainous regions, appropriate traffic management may be achieved, even if all ATMS facilities and systems are not necessarily provided, because they do not see much traffic volume compared to that on highways in urban areas. However, the most appropriate and ideal traffic management, i.e. traffic information collection and provision, can be realized by providing appropriate ATMS facilities and systems at appropriate locations and intervals for all highways consisting of the targeted highway network.

On mountainous highways in India, natural disasters in the rainy season such as landslides, rock falls, debris flow, etc., and road damages caused by natural disasters are one of the major causes to disturb safe and smooth traffic. Under such a circumstance, countermeasures for natural disasters and road damages are the most crucial issues for highway operation and maintenance. However, sufficient budget, time, and human resources are necessary to conduct physical countermeasures for all slopes by such as concrete frame, steel net, and/or anchor, and it may be even unrealistic to achieve the goal within a short period of time. Until countermeasures for natural disasters will be conducted, it shall be therefore required to ensure safe road traffic conditions and human lives on highways by proper traffic management, such as monitoring weather information, strengthening inspection, and conducting road closure when natural disasters are more likely to occur. An approach is to provide minimum ATMS facilities and systems such as meteorological data systems, information dissemination systems, etc. even if a highway does not have enough traffic volume in mountainous regions.

This guideline recommends that ATMS facilities and systems are installed to mountainous highways ~~in~~ category wise, i.e. (1) major arterial highways in mountainous regions with high traffic volume such as highways connecting state capitals, (2) mountainous highways with middle traffic volume (not belonging in (1) and (3)), and (3) mountainous highways located in a rural area and with low traffic volume. The reason why classifying these three categories is that it is an effective and realistic approach for highways development and operation in mountainous regions. Table 2-5 shows the ATMS facilities and systems to be installed on highways in each category. The method how to classify a highway into three categories from (1) to (3) may be decided by the road administrator for actual implementation; however, one possible method would be that DPR consultant identifies it and get permission from a project owner during DPR stage according to characteristics of a highway under study, in terms of traffic condition (estimation), weather condition, a strategic priority of the highway, etc.

Table 2-5: Minimum ATMS Facilities / System in Category Wise

ATMS facilities / system		Category (1) High Volume	Category (2) Mid Volume	Category (3) Low Volume
Information Collection	Patrolling	○	○	○
	Video Surveillance System (CCTV)	○	○	△
	Video Incident Detection System (VIDS)	○	△	-
	Emergency Communication System (Including "Helpline 1033")	○	△	△ (Helpline 1033)
	Meteorological Data System	○	○	○
	Weigh-in-Motion & Weigh Bridge System	○	○	-
	Automatic Traffic Counter cum Classifier (ATCC)	○	-	-
	Mobile Radio Communication System	○	-	-
Information Centers	Traffic Control Center (TCC)	○	△	-
	Facility Control Center	○	△	-
	Disaster Prevention Center	○	○	○
	Data Transmission System	○	○	○
Information Dissemination	Variable Message Signs (VMS)	○	○	○
	Portable VMS - on Vehicles	○	△	-
	Vehicle Actuated Speed Display	○	-	-
	Travel Time Estimation System (TTES)	○	-	-
	Highway Advisory Radio (HAR)	○	△	△
	Internet or Mobile Services	○	-	-

Note: "○": shall be installed, "△": preferably installed, "-": Not applicable

Source: JICA Expert Team

As stated above, it is required to provide appropriate ATMS facilities and systems at appropriate locations for proper traffic management to the whole highway network. In this regard, Table 2-5 does not necessarily indicate a permanent provision policy of ATMS, rather it shows the policy for the minimum provision of ATMS when highways with low and/or middle traffic volume are constructed or improved. A road administrator may consider installing more ATMS facilities and systems than those listed in Table 2-5, where necessary, even if a highway is categorized into category (2) or (3).

Another application of ATMS facilities is the Early Warning System, which aims to secure higher road safety in a high-risk section by regulating road traffic based on real-time rainfall data and/or slope monitoring data. The detail is described in Section 2.5.

2.4 Traffic Management

2.4.1 Traffic Management Tasks

Traffic management tasks can be broadly classified into the following categories.

(1) Incident Management

Any non-recurrent event which causes a reduction of roadway capacity or abnormal increase in demand is an incident. An incident can be 'Predictable' (e.g. construction/maintenance activities and special events like festivals, etc.) or 'Unpredictable' (e.g. landslide, inclement weather, etc.). During an incident, part of vehicles during a certain duration of time (measured in say, vehicle-hours) keeps on occupying a roadway length affected by the incident and does not discharge to the downstream direction. The vehicles trapped in the incident suffer delays, which are equal to the sum of the time required for incident detection, intervention, road clearance, and restoration to the original condition. Incidents, if not managed properly, may also cause secondary accidents.

Incidents (particularly, unpredictable) can be detected by the patrolling team, any passing by vehicle, or the users directly involved in the incident. Incidents can also be detected in real-time by sensors if placed at the site. The most effective method is by video sensing, though other sensors (loop detectors and infrared / microwave) can also give a warning by detecting a sudden drop in speeds and flows, indicative of an incident, which can be verified and acted upon.

Managing predictable incidents requires on-site traffic control and dissemination of advanced information to the users. Unpredictable incidents would additionally require detection, verification, and emergency intervention to rush help and clear the roadway. The objective of incident management is to minimize the total time required for detection, intervention, and clearance of roadway. These managements become possible by real-time detection of incidents, well-planned logistics of intervention team (priority movement of emergency vehicles including contraflow), traffic control at the incident site, guiding users through fixed or portable variable message signs.

(2) Emergency Management

Emergency management is part of incident management, which is already discussed above. It is much more than routine traffic management. Severe or fatal accidents, natural disasters, multi-vehicle collisions, and/or collapse of a structure are a few examples of emergencies. This may involve, apart from traffic management, evacuation and rescue of the persons affected by emergencies, rushing them to hospitals or trauma centers, and clearing the roadway by removing the damaged vehicles or properties. Time and the logistics of emergency operations are critical in emergency management. Since multiple agencies have to swing into action (in accordance with the established protocol and SOPs), move into and out of the site of emergencies, and conduct the operations at the site, the logistics of such movement is the major traffic management task.

Traffic on the affected section of roadway is dominated by the movement of emergency vehicles and equipment (e.g., fire tenders, ambulances, cranes, heavy machinery) while roadway space is crowded by long queues of vehicles forced to stop due to emergencies. The normal traffic has to be stopped and diverted, where necessary, till the emergency intervention is completed. Traffic management task during emergencies is thus threefold, 1) to stop traffic from approaching the affected section, 2) having stopped the traffic, to divert it to some other route, if available, and 3) to make way for emergency vehicles to drive through the traffic.

Once regular traffic is stopped, the queue will start building up upstream of the emergency site and there will be lean or no flow on the downstream side.

(3) Providing Information with Road Users

Road users are recommended to be informed immediately about what is happening on a highway in real-time (e.g. incidents, congestions, accidents and emergencies, weather changes) and subsequently, appropriate action(s) (reducing speed, patient and cautious driving, taking a diversion, not entering the highway, estimated travel time) shall be guided. Planned activities (on-going maintenance, lane closure, or any other specific events) on a highway, which are likely to cause delays or congestion, requires to be informed to the road users in advance. Dynamic information is also necessary for road users, which is about their travel routes and traffic conditions. The Center is available for any road users to access when help and/or assistance is needed (lost ways, vehicle breakdown, lack of fuel, medical emergencies).

The real-time user interface usually interacts through Variable Message Signs (VMS), portable VMS, Highway Advisory Radio (HAR), and internet/mobile services. Advance information can be sent through the internet, dedicated telephone line, or commercial radio. Individual road users and the Center can communicate with each other through Emergency Call Boxes (ECB) or mobile phones. As mentioned in Chapter 2.3.3, ECBs shall be installed in tunnels and other locations where a mobile network is not available.

1) Real-Time Information

Variable message signs (VMS): These are the most powerful and effective user interfaces that enable the dissemination of real-time information to road users. VMS display consists of matrices of pixels, which are lighted by a power source. There can be numerous types of messages to be displayed depending upon the requirement, some of which can be as follows;

- ✓ Route information
  - (name of the place)...km;
  - Next filling station/wayside amenity...km.
- ✓ Traffic information/advisories (alpha numeric texts)
  - Time to destination;
  - The highway ahead closed for an emergency, take a detour (highway number/distance);
  - Maintenance activity ahead, reduce speed;
  - Incident ahead, reduce speed;
  - Emergency ahead, stop, take a detour;
  - Give way to emergency vehicles;
- ✓ Weather information/advisories
  - Expect heavy rains/high winds/fog / poor visibility ahead, reduce speed; and
  - Expect a slippery surface ahead, reduce speed.

Highway Advisory Radio (HAR): All the information on the route, traffic and weather condition, etc. can be broadcast on dedicated HAR by setting up transmission towers along the highway connected (in a wired / wireless network) to a broadcasting station at the Center. The broadcast can be picked up and received by onboard radio receivers when a vehicle is driving within a certain range of distance from the towers. Transmission is possible on any frequency within the frequency band allocated by the relevant Department of Telecommunications. Low-frequency broadcast, however, may have poor quality due to interference from power lines in their vicinities.

2) Advance Information

Internet: The Center can upload and periodically update its webpage during certain hours of the day relating to road information on a route (e.g. maintenance activity, lane closures due to natural disaster, etc.) and traffic information (e.g. specific events, incidents, etc.), which road users can use to plan their trips.

Commercial radio: The Center may inform the route and traffic condition on a highway by leasing time slots at certain time intervals on commercial radio channels to help road users make their travel decision based on a prevailing route and traffic conditions before entering the highway or change their decisions if they are already on the highway.

Help line number: Any road user may contact the Center via Help Line number (e.g. Helpline 1033) and receive real-time or advance information.

3) Direct Road User – the Center Communication

Emergency Call Boxes (ECB): This is the simplest and easiest way a road user can directly contact the Center and ask for any help. Because ECBs location can be tracked, the Center can adjust promptly for immediate help on receiving information from the road user(s) in an emergency situation, a driver passing by (including the passenger on his / her car), or the patrolling team.

Mobile phone: Road user(s) in an emergency situation can communicate with the Center on mobile phone and explain his / her location. A GPS enables a smartphone to transmit its location automatically to the GPS receiver at the Center.

2.4.2 Incident Management

(1) Traffic Accident

Traffic accident(s) may be generated due to vehicle collision, fall, or spillage of cargo blocking the traffic lane(s). Road alignment of mountainous highways is basically not good as compared to that of highways in the plain area, plus weather condition is more severe. In this regard, hill roads have a higher risk of traffic accidents.

(2) Information Collection

The primary source of information may be mobile phones from road users or passengers, calls from maintenance crews, patrolling teams, ECBs, police patrols, etc.

The next step after the receipt of information is to identify the precise location and nature of the accident, as well as the display, recording, and communication of this information to the appropriate agencies. The center personnel may verify accidents and communicate with incident responders on the scene, or provide details to emergency agency dispatchers. These shall include;

- ✓ field units (i.e. police) at an incident site
- ✓ CCTV images, if any
- ✓ combining or fusing information from multiple mobile phone cellular calls

(3) Information Disseminations

Information of the accident/incident should be reported to road users at major highway junctions or on a concerned route well in advance of the incident location. Dissemination of such information is one of the primary services provided by the Center, and the techniques may include;

- ✓ Commercial radio and television
- ✓ Variable message signs (VMS)
- ✓ Portable variable message signs
- ✓ Highway advisory radio (HAR)
- ✓ Internet / on-line services (mobile)

(4) On-Site Actions

This is the action, coordination, and management of the appropriate personnel, equipment, and communication links and road user information media as soon as it is reasonably certain that a traffic incident has occurred. Techniques may include;

- ✓ inter-agencies response planning and mutual-aid agreements.
- ✓ intra- and inter-agency(s) communications. This includes voice radio interoperability, data and video links between public safety communication centers, the Center, and highway operations centers.
- ✓ personnel and logistics support.
- ✓ equipment storage sites.
- ✓ advanced response vehicles that include a mobile communications platform, GPS, and other features to facilitate efficient response. The prime requirement would be 1) to send Ambulance to the incident site, 2) Traffic Regulation / Control / Management, 3) Removal of Vehicles or Cargoes involved in the incident, 4) Vehicle Fire Extinguish.

1) Ambulance Services

Ambulances may be parked right next to the place of accident/incident, if necessary. A senior representative as a member of the Management Team shall ensure that a proper record is kept of the activities on the scene, and of decisions made.

The first team arriving at the scene of the incident, shall note the details, prioritize patients, aid the injured, and place warning signs to road users. Where possible, assist the concerned law and order authorities with regard to the following;

- ✓ Ensure that the necessary blood samples are collected by a suitably qualified person where substance misuse is suspected
- ✓ Inform concerned authorities, investigation team when the particulars of patients can be collected prior to departing from the incident scene

- ✓ Assist concerned authorities to complete outstanding patient details after the incident has been cleared, if the particulars of a patient could not be obtained on the scene
- ✓ Advise concerned authorities of the particulars of the ambulance driver if a patient has died on the highway heading to a hospital

In the event of an incident involving hazardous materials:

- ✓ Wear protective clothing before entering into a dangerous zone
- ✓ Remove the victim from the source of exposure
- ✓ Remove all contaminated clothing from both the patient and personnel
- ✓ Obtain the Material Safety Data Sheet from the Fire & Rescue services to determine the requirements and limitations for medical attention after exposure to a specific hazardous material
- ✓ Transport the injured person(s) to the nearest suitable hospital(s)
- ✓ Ensure that bodies of deceased victims are either placed in body bags or properly covered as soon as possible

2) Traffic Management Operation

The operation of traffic management measures at an incident site and on facilities are affected by the traffic incident. Effective traffic management minimizes traffic disruption while maintaining a safe workplace for responders and reducing the likelihood of secondary accidents. Techniques include;

- ✓ Preparation
  - Alternate route planning, where available
  - Availability of cones, flares, warning signs, arrow boards, portable VMS, and other traffic control resources
  - Availability of traffic control devices and traffic signals
- ✓ Flow management at the scene
  - Establishment of point traffic control at the scene
  - Management of highway space
- ✓ Flow management on alternate routes
  - Establishment and operation of alternate routes
  - Active management of traffic control devices
- ✓ Reduce long-term traffic incident duration

3) Removal of Vehicles Damaged in the Accident

The management team shall ensure that unnecessary obstructions have been cleaned-up. In the event of fatalities, possible reckless driving, and/or where government or military vehicles are involved, it shall be ensured to collect the detailed information and to preserve evidences to the extent possible. The removal of vehicles from the site shall be authorized and controlled in close coordination with concerned authorities, investigating officers by determining which vehicles, if any, and need to be removed by a tow operator.

It is necessary to ensure that the following information is made available by a tow operator before a vehicle is towed away from the site;

- ✓ Name, address, and telephone number of the operator,
- ✓ Registration number of the tow vehicle,
- ✓ Name, address, and telephone number of the owner of the damaged vehicles,
- ✓ Registration number of the damaged vehicle, and
- ✓ Destination of the damaged vehicle.

Regulations for - Tow, Recovery, and Crane Operators

An adequate number of the towing vehicle(s) shall be allowed on site. No additional towing vehicles shall be arranged at the site of an incident to avoid possible confusion. The tow vehicle is parked in the adequate zone of parking at the fringe of the incident site, and access to the accident/incident point only after the authorization from the Management Team. The towing vehicle which does not conform to legal requirements shall not be allowed to tow and shall be requested to leave the incident site.

In case of minor incidents, senior officer on scene immediately after arrival on the scene may ensure that the same is noted.

4) Vehicle Fire Extinguish

The vehicle for fire-fighting may park at the accident, if necessary. A senior representative as a member of the Management Team shall ensure that a proper record of the activities on-site, and decisions made shall be kept. The fire and rescue service shall be informed of the jurisdictional area of the incident.

For motor vehicle accidents, all fire-fighting and fire control operations shall be carried out following investigation and rescue operations. Also, potentially hazardous material shall be identified.

In the event of an incident involving hazardous material, the following activities shall be undertaken;

- ✓ Obtain material data sheet of the vehicle carrying the hazardous material
- ✓ Supply a copy of the material data sheet to the Ambulance team on site
- ✓ Inform to mobilize the necessary hazardous material specialist team(s)
- ✓ Prevent or minimize pollution to the environment (paying special attention to fire run-off water)
- ✓ Relay the dangers relevant to the hazardous material involved to all members of the Management team
- ✓ Ensure the warning of potential dangers to the public
- ✓ Prohibit smoking in the adjacent area of the incident
- ✓ Effect on-site chemical/gas containment
- ✓ Identify the incident site pertaining to the area of isolation and evacuation
- ✓ If necessary, initiate the necessary evacuation procedures in conjunction with the full Management team

2.4.3 Inclement Weather

(1) Information Collection

The effects of weather on highways differ from area to area according to geography, topography, elevation, and road structure (e.g. cut, embankment, bridge). In the case of mountainous highways, the weather may change drastically within a short distance/period on a road. In this regard, it is essential to monitor road weather accurately in real-time in order to perform road operations, to secure safe and smooth traffic flow by providing information of weather conditions to road users, and to promote efficient use of a road, etc. For these purposes, the installation of various meteorological observation equipment is recommended on mountainous highways. The details are explained in the following subchapters.

(2) Meteorological Observation Facilities

1) Overview

Meteorological observation facilities are recommended to be installed on roadsides to collect weather data necessary for adequate road management, such as by the Early Warning System (EWS), providing road users with caution of heavy rainfall and dense fog. The detail of EWS is presented in Chapter 2.5.

2) Meteorological Observation Facility System Chart

Basically, air temperature, road surface temperature, the amount of rainfall & snowfall, wind direction & speed shall be measured through Meteorological Observation Facilities.

Weather condition data for mist, road surface icing, etc. shall also be collected according to the typical meteorological conditions and road management conditions at regions where the highways are located.

3) Instrument Configuration

Table 2-6 shows standard facilities to be installed as the constitution of the meteorological observation system.

Table 2-6: Meteorological Observation System

Item	Meteorological Observation Facilities
Air temperature	Thermometer
Rainfall	Rain / Snow gauge, Precipitation sensor
Snowfall	Rain / Snow gauge, CCTV, transmissivity meter, or BS type visibility meter
Mist	CCTV, transmissivity meter, or BS type visibility meter
Wind	Anemoscope / Anemometer (wind vane type)
Earthquake	Seismograph
Road icing	Road surface temperature gauge (underground thermometer)

Source: JICA Expert Team

(3) Standard Instruments

1) Thermometer

A thermometer is used to continually measure exterior air temperature based on the resistance fluctuations caused by the temperature of a platinum temperature-resistant body.

2) Rainfall / Snow Gauge

A rainfall/snow gauge collects the amount of rain or snow and automatically weighs it according to the tilt of its tipping bucket to measure the precipitation.

3) Precipitation Sensor

A precipitation sensor immediately senses the beginning and the end of rainfall or snowfall. In this way, it obtains up to the minute information about the beginning of rainfall, a period when road conditions are particularly slippery. A precipitation sensor can also automatically distinguish between snow, rain, and mist if it is combined with a VI meter or BS meter.

Table 2-7: Judgment of Weather using Precipitation Sensor and VI Meter

	Output		
Precipitation sensor	○	○	×
VI meter (or BS meter)	×	○	○
Judgment results	Rain	Snow	Mist

Note: "○": Detected, "×": Not detected

Source: JICA Expert Team

4) Visual Obstruction Sensors

Visual obstruction sensors include a transmissometer (VI meter) and a Backward Scattering visibility meter (BS meter). VI meter, which consists of a floodlight and light receiver installed facing each other to measure light transmissivity, is appropriate where the main objective is the measurement of mist.

BS meter, a device consisting of an integrated floodlight and light receiver aimed in the same direction, measures the light scattered backward from mist or falling snow (reflected light). It is appropriate for use where the principal phenomenon observed is the obstruction of visibility by falling snow.

5) Meteorological CCTV

CCTV system is an appropriate way to provide images confirming that actual conditions on a road conform to values provided by monitoring instruments. It is also a good method to clarify road conditions that are difficult to measure using meteorological observation instruments. (e.g. blowing snow or amount of snow accumulated on the road surface in a snowy cold region).

6) Anemoscope / Anemometer

Anemoscope/anemometer, which is used to measure the wind speed and its direction, is an aero vane pane type consisting of a propeller that measures the wind speed and a tail plane.

7) Seismograph

A seismograph detects the earthquake movement acceleration of two components of horizontal and vertical motion, its processor records the time of the earthquake and its acceleration wave profile and calculates the SI value, measured intensity, maximum acceleration, etc.

8) Road Surface Thermometer and Soil Thermometer

A road surface thermometer and a soil thermometer perform measurements with two thermometers (fluctuation in resistance caused by the temperature of a platinum temperature resistant body) installed at different depths under the ground surface to predict the icing of the surface of a through highway.

(4) Information Provisions

Analysis of the meteorological data recorded on site along with the weather forecast is performed by the concerned agency or road operator with assistance from the concerned agency. Specific data in a specific section on a highway is recommended to be generated and conveyed to road users for possible precautions by road users.

Heavy rainfall, the formation of fog, and snow impedes vehicle speed and visibility and also decrease driving safety by causing a hydroplaning effect. These facts need to be effectively conveyed to road users through VMSs, HAR, etc.

(5) On-Site Actions

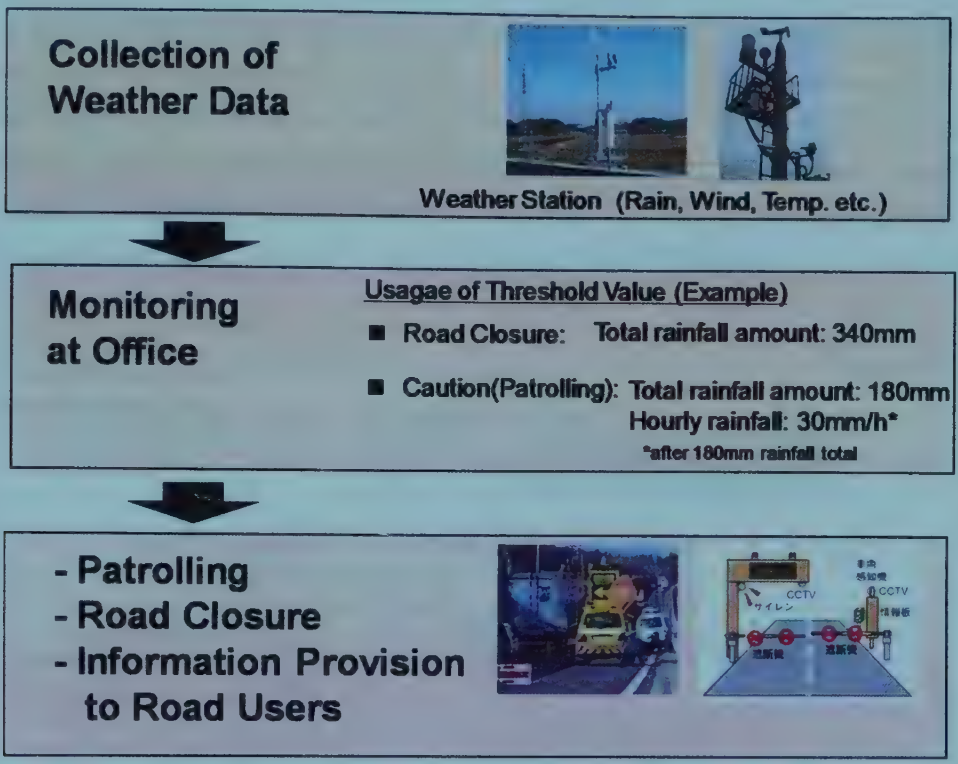
1) Adequate drainage facilities shall be provided to the highway road section, especially at the location of cross slopes and/or sag profile points, in order to drain out the precipitates. Road side drains including chutes shall be kept clean for smooth flow of rain water. The detailed direction of drainage facilities is included in Planning Guideline.
2) The macro structure of the road surface at probable locations may be enhanced for draining out the water from the contact area between the tires and pavement in order to prevent the hydroplaning effect. Alternatively, a porous asphalt-wearing course may be effective to use.
3) The measures to deal with snow accumulation and the icing on highways in snowy cold regions include mechanical snow removal and spreading de-icing chemicals on roads in snowfall areas. Appropriate storage of materials and the equipment along with operators shall be present in or nearby operating yard/wayside amenities (rest areas).

2.5 Early Warning System (EWS)

2.5.1 Outline of Early Warning System (EWS)

An early Warning System (EWS) is a system to proactively regulate and close a section before the disaster occurs in order to secure the safety of road users, together with adequate slope protection work. EWS has been conducted by Japanese road operators over the last several decades to further enhance the safety of hill roads.

For the implementation of EWS, a road operator sets a threshold (criteria value) to conduct patrol and road closure, based on the history of rainfall and disaster in a concerned section in a mountainous area. Weather stations are installed along the roadway to monitor real-time weather conditions so that road operators can perform patrolling and road closure at the right time and right place. It is to be noted that the introduction of EWS does not mean that slope protection is not necessary, but that it is a method to enhance road safety. The concept of the Early Warning System is shown in Figure 2-16.


Collection of Weather Data
Weather Station (Rain, Wind, Temp. etc.)
Monitoring at Office
Usagae of Threshold Value (Example)
■ Road Closure: Total rainfall amount: 340mm
■ Caution(Patrolling): Total rainfall amount: 180mm
Hourly rainfall: 30mm/h*
*after 180mm rainfall total
- Patrolling
- Road Closure
- Information Provision to Road Users
CCTV
サイレン
CCTV
情報板
遮断機
遮断機

Source: JICA Expert Team

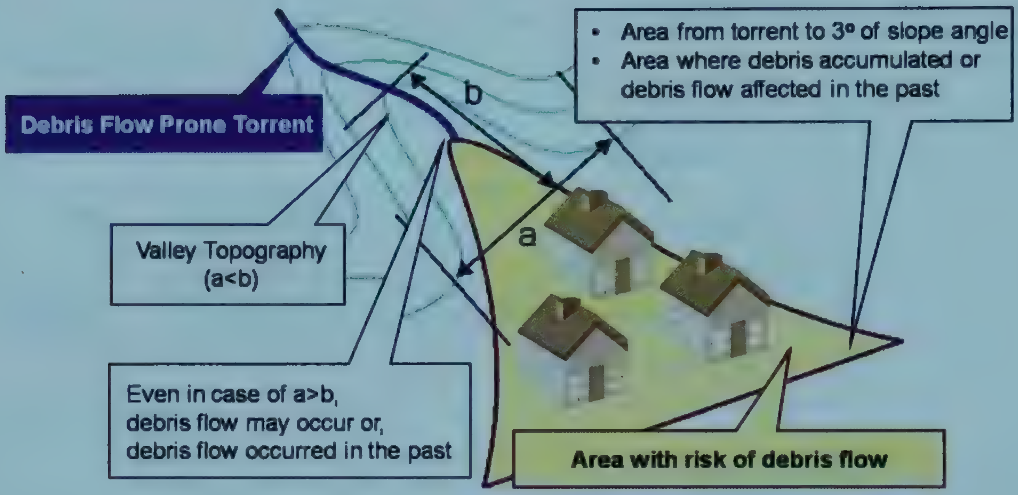
Figure 2-16: Concept of Early Warning System

This section aims to present practical approaches and procedures on how to set appropriate criteria values and to implement safety measures such as traffic regulation, road closure, etc. before any damage occurs. The procedures include analysis of a relationship between rainfall and road disasters by using past data on road disasters caused by rainfall.

As for the relationship between rainfall and road disasters, however, multiple and complicated factors exist, such as topographical/geological conditions on a slope and/or hinterland, inflow/outflow conditions to/from outside the highway, maintenance slope or drainages, local rainfall condition, etc. Hence, it is almost impossible to set the uniform criteria value to secure the safety of road users. For example, when a criteria value is set that enables safety to all rainfall damages, the criteria value becomes too low, which may lead to lost reliability of expressways because it leads to unnecessary high frequent and longer time of road closures. In an opposite manner, when the criteria value is set high, the risk of damage for road users may increase and/or huge cost is required to countermeasures to prevent road disasters such as slope protection, etc.

Road disaster happens due to rainfall in small amounts and/or after a considerable lag as well as occurred outside the right-of-way. Also, some were unable to obtain an obvious relationship with rainfall, such as landslides, which is difficult to identify the cause, as well as debris flow from outside the highway, etc. Therefore, the basic philosophy of the most appropriate criteria value is that the incident rate of road disasters is high after reaching the criteria value, and the probability of unnecessary countermeasures such as traffic regulation, road closure is small. For this setting, it requires to consider the traffic characteristic, rainfall experience, and damage record on the target highway in addition to rainfall characteristics.

This guideline deals with the relationship between rainfall and road disaster (slope disaster); however, it does not include disaster due to debris flow in its scope. Debris flow prone torrents is basically an area with a mountain stream where debris flow poses a risk of damaging house and roads. The fundamental approaches of survey for such area are to grasp by site investigation or topographic map reading, 1) the mountain stream with valley topography, that debris flow occurred in the past or that may have a risk of debris flow, as well as 2) the area where the possible largest debris flow may occur based on the situation of land shape and deposition state of sediments in the past and/or flood experience by debris flow in the past, with a rough indication of slope angle between 15° and 3° which may have a high risk of debris flow.


Debris Flow Prone Torrent
b
a
Area from torrent to 3° of slope angle
Area where debris accumulated or debris flow affected in the past
Valley Topography (a<b)
Even in case of a>b, debris flow may occur or, debris flow occurred in the past
Area with risk of debris flow

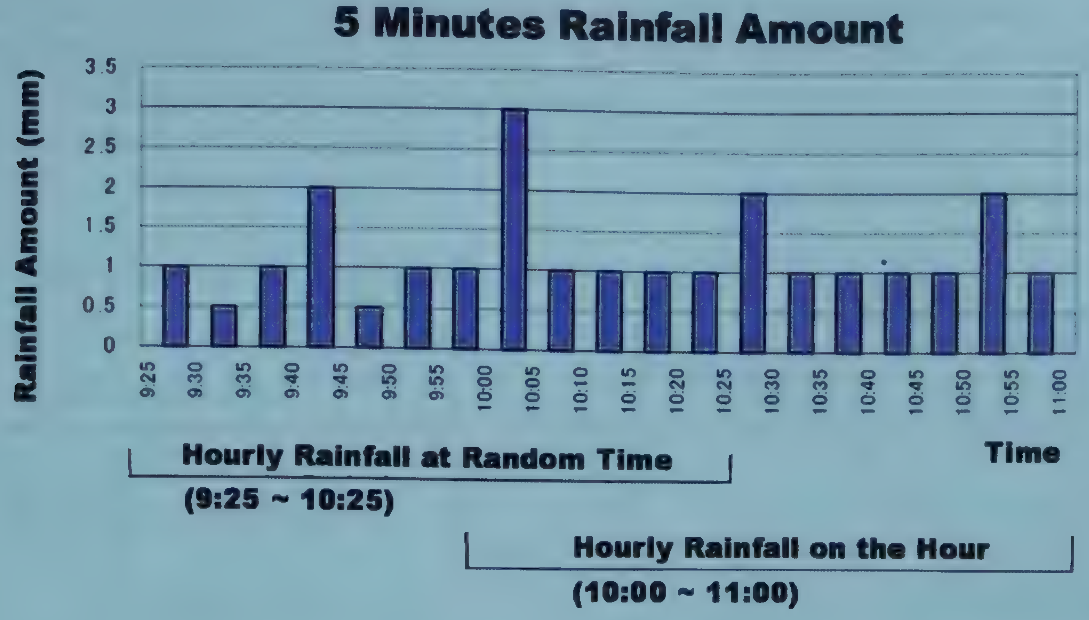
[5]

Figure 2-17: Concept of Debris Flow Prone Torrents and Area Where Has Risk of Damage by Debris Flow

2.5.2 Definition of Rainfall

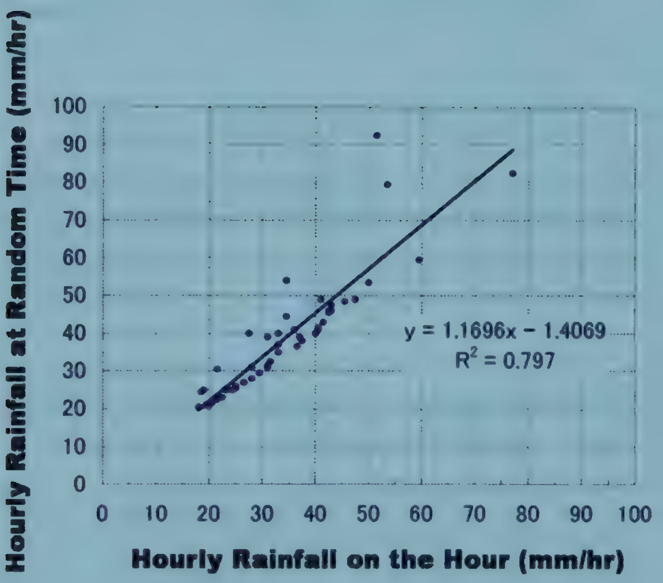
(1) Hourly Rainfall

It is efficient to use "Hourly rainfall on the hour" when statistical processing is taken for the hourly amount of rainfall because past data of rainfall is generally saved every hour on the hour. On the other hand, it is recommended to use "Hourly rainfall at arbitrary hour" to decide and operate criteria values, because it is preferable to manage highways based on the rainfall amount and intensity in real-time. On Japanese expressways, because it is obvious that there is a correlation, shown in Figure 2-19, for "hourly rainfall at arbitrary hour" and "hourly rainfall on the hour" from the past data of rainfall, correction is made on the difference when setting criteria value. Here, "Hourly rainfall at an arbitrary time" is the rainfall amount an hour before the arbitrary time and 12 times of 5-minutes rainfall amount in total (refer to Figure 2-18).



Source: JICA Expert Team

Figure 2-18: Definition of Hourly Rainfall



Source: JICA Expert Team

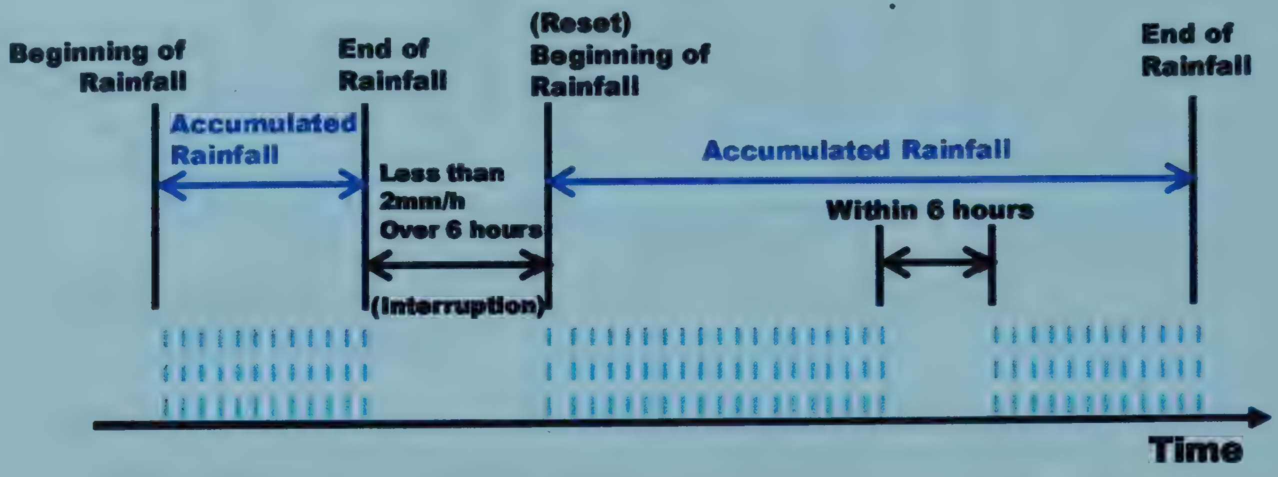
Figure 2-19: Relationship between "Hourly rainfall at arbitrary hour" and "Hourly Rainfall on the hour"

(2) Accumulated Rainfall

Various definitions are used by countries or organizations for the concept of accumulated rainfall. Therefore, it is essential to definite a uniformed criteria value of accumulated rainfall. For Japanese expressways, "Accumulated Rainfall" is defined as "accumulated amount of rainfall when continuous rainfall more than 2mm per hour is observed from the beginning till the end without any interruption for over 6 hours" (refer to Figure 2-20).

This definition is based on the analysis of the past damages due to rainfall for the interruption time (less than 2mm per hour) at 3 hours, 6 hours, and 9 hours for the method of taking interruption time of rainfall, revealing the following fact.

The shorter the interruption time is set, 1) each rainfall from the beginning to the end is subdivided and thus, it is difficult to read rainfall characteristics from accumulated rainfall amount, 2) because each rainfall is subdivided, accumulated rainfall amount may become extremely small at the time of damage occurrence. On the other hand, the longer the interruption time is set, 1) accumulated rainfall amount at the time of damage occurrence may vary widely. And the reason why the rainfall is defined as "less than 2mm per hour" is that of considering the "measurement error", etc., by the observation equipment.



Source: JICA Expert Team

Figure 2-20: Definition of Accumulated Rainfall

(3) Heavy Rain Advisory and Warning

In Japan, the meteorological bureau predicts possible rainfall, and by using standard rainfall values based on the rainfall prediction values, "Emergency warning on heavy rain", "Heavy rain warning" or "Heavy rain advisory" is announced. Each definition is as follows.

- ✓ Emergency warning on heavy rain: This warning is announced when heavy rain is predicted by severe typhoons or localized torrential rain front. When the warning has been announced, it can be significantly anticipated that severe sediment disasters or floods may occur. The announcement continues during a period when a higher risk of severe sediment disaster still remains even if the rain stops.
- ✓ Heavy rain warning: It is announced when severe sediment disaster or flood damage due to heavy rain may probably occur. The announcement continues during the time when a higher risk of severe sediment disaster, etc. still remains even if the rain stopped.
- ✓ Heavy rain advisory: It is announced when sediment disaster or flood damage due to heavy rain is predicted. The announcement continues if the risk of sediment disaster, etc. still remains even if the rain stopped.

In India, the National Weather Forecasting Centre, India Meteorological Department, Ministry of Earth Sciences makes an announcement of warning in four phases according to rainfall amount and area, which are "Red (Most Vigil (Take Action))", "Orange (Be prepared/updated (Keep Vigil)", "Yellow (Be aware (Be updated))" and "Green (No Warning)".

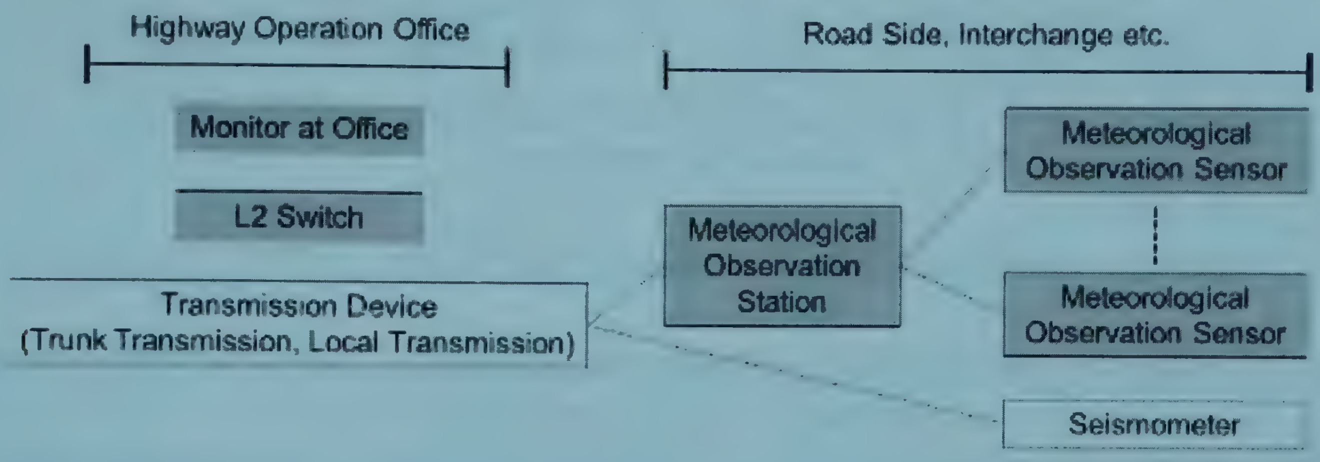
2.5.3 Meteorological Observation Station

(1) Installation of Meteorological Observation Equipment

To prevent the occurrence of disaster and take appropriate response promptly when suffering from disaster, a road administrator needs to grasp the latest weather condition accurately on their operating highways. This can be realized by installing meteorological observation facilities along the highway, such as thermometer for road and air, wind direction and speed, rainfall, and visibility meter. Weather information collected from local weather observation stations shall be monitored at a highway operation office in charge.

(2) Overall Structure of Meteorological Observation Facilities

Meteorological observation facilities consist of observation sensors and office monitoring equipment, placed at the roadside of highways and a highway operation office, respectively. The standard constitution of the system is shown in Figure 2-21.


Highway Operation Office
Road Side, Interchange etc.
Monitor at Office
L2 Switch
Transmission Device
(Trunk Transmission, Local Transmission)
Meteorological Observation Station
Meteorological Observation Sensor
Meteorological Observation Sensor
Seismometer

Source: JICA Expert Team

Figure 2-21: Overall System Constitution of Weather Observation Station

(3) Specification / Outline Design / Arrangement of Weather Observation Facilities

The outline of the design and standard arrangement for meteorological observation facilities is explained in Section-2.3 and Section-2.4.

2.5.4 Method of Setting Criteria Values

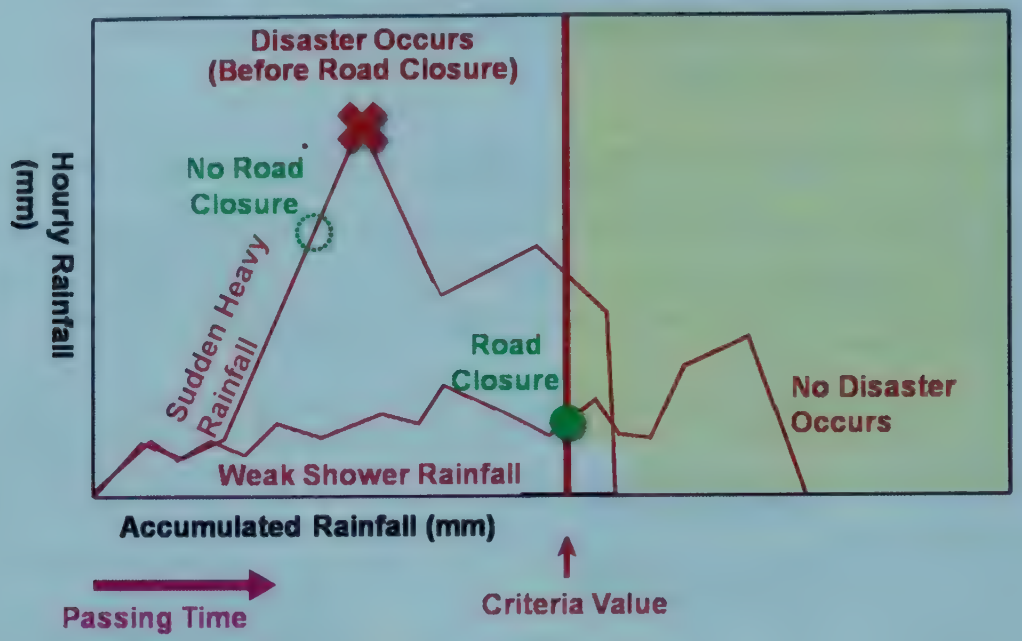
There are several methods to determine criteria values of road operation for road closure during heavy rainfall. The following sections present typical setting methods adapted in Japan.

(1) Method of "Accumulated Rainfall"

As for national highways etc. in Japan, appropriate traffic safety measures (road closure, etc.) are generally taken when accumulated rainfall (continuous rainfall amount) exceeds a criteria value, which is predetermined by the method of accumulated rainfall. When rainfall is zero (0) or extremely less (less than 2mm per hour etc.) in a given period of time (approx. 3 hours is the certain time), accumulated rainfall is reset to zero (0).

Since the setting of this criteria value is judged simply by the amount of accumulated rainfall, the major advantage of this method is the easiness to predict the start time of traffic regulation (road closure, etc.) and arranging workers (manpower) and equipment for traffic regulation.

On the other hand, its major disadvantage is that a factor of rainfall intensity is not considered in the criteria value, and therefore a road operator may take measures against a disaster caused by local heavy rainfall for a short period of time. Even if weak shower falls that is unlikely to cause sediment disaster, it requires to conduct traffic regulation when accumulated rainfall amount reached the criteria value.



[6]

Figure 2-22: Concept of Traffic Regulation by Method of Accumulated Rainfall

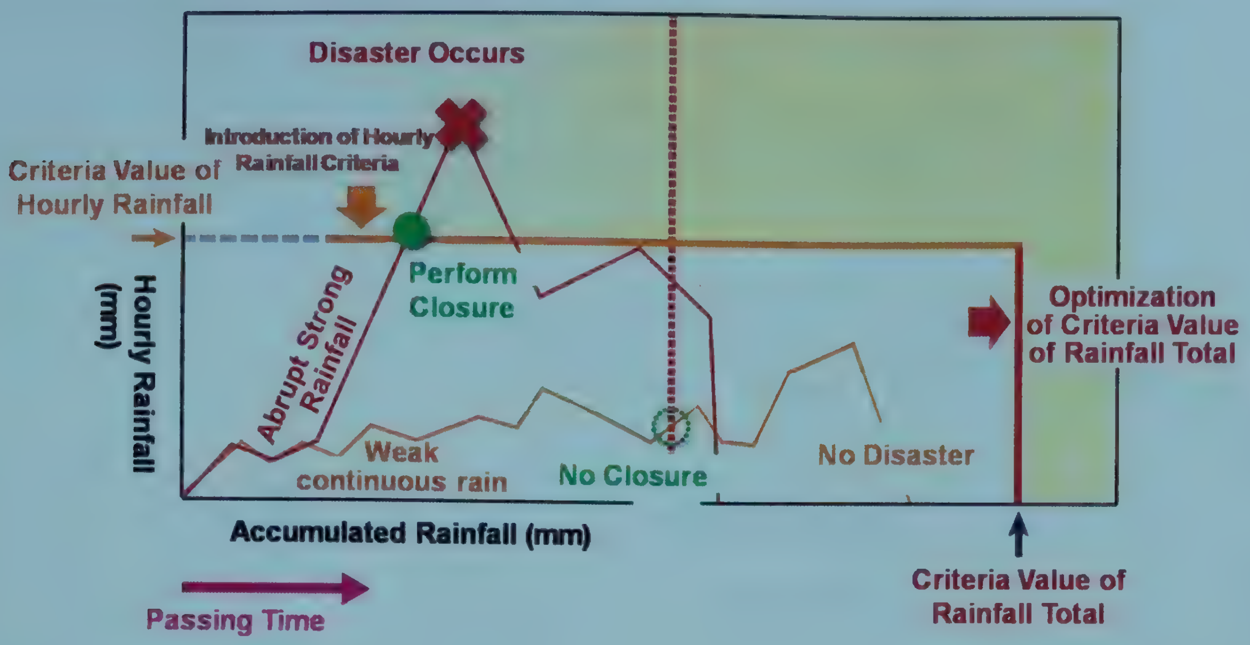
(2) Method of “Combination of Accumulated Rainfall and Hourly Rainfall”

The method of “Combination of Accumulated Rainfall and Hourly Rainfall” has been adapted as a criteria value on expressways in Japan. As the name of the method says, it takes both factors of accumulated rainfall and hourly rainfall. By plotting the history of accumulated rainfall on the horizontal axis and hourly rainfall on the vertical axis, rainfall characteristic in a target section is visually studied. Criteria value is then determined by considering past damage caused by rainfall. Based on the relationship between the experience of rainfall amount and occurrence of a disaster, the criteria value is adjusted more precisely.

This is a method to take account of the history of rainfall and damage statistically, which is effective for a section where various geological conditions appear. In addition, this criteria value can be set comprehensively by calculating the characteristic of each slope.

In the meanwhile, it requires to close road immediately after exceedance of a criteria value in order to operate highways properly. Therefore, it requires to prepare the organization and equipment sufficiently beforehand so that it enables to develop arranging workers (manpower), equipment, etc. immediately.

For this reason, this method can be adapted for roads where road closure is possible promptly, for example, access-controlled expressways where workers (manpower) are arranged always at a toll gate 24x7. However, its introduction may be challenging for roads that require time for arranging workers and equipment at the time of conducting a road closure. Table 2-8 summarizes the two methods of “Accumulated Rainfall” and “Combination of Accumulated Rainfall and Hourly Rainfall”.


Disaster Occurs
Introduction of Hourly Rainfall Criteria
Criteria Value of Hourly Rainfall
Hourly Rainfall (mm)
Perform Closure
Abrupt Strong Rainfall
Weak continuous rain
No Closure
No Disaster
Optimization of Criteria Value of Rainfall Total
Accumulated Rainfall (mm)
Passing Time
Criteria Value of Rainfall Total

[6]

Figure 2-23: Concept of Traffic Regulation by Combination Method

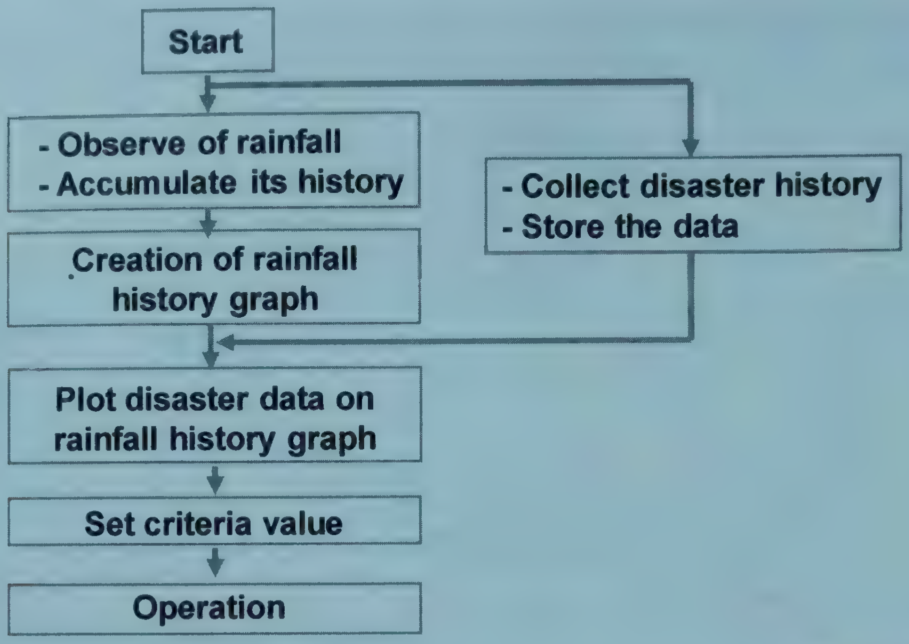
Table 2-8: Methods of "Accumulated Rainfall" and "Combination of Accumulated Rainfall and Hourly Rainfall"

Method	Method of Accumulated Rainfall	Method of Combination of Accumulated Rainfall and Hourly Rainfall
Road Category	Mainly national highway	Mainly expressway
Criteria (Threshold)	Accumulated rainfall amount only	Accumulated rainfall amount + Hourly rainfall amount
Advantage	Easiness of operation (arrange of workers and equipment)	More reliable method (both accumulated rainfall and rain intensity are taken into account)
Disadvantage	Heavy rainfall in a short period of time is not taken into account	Appropriate monitoring systems and human resources are necessary

Source: JICA Expert Team

2.5.5 Criteria Setting on Accumulated Rainfall / Hourly Rainfall Method

Figure 2-24 shows a basic procedure for setting a criteria value on the method of "Combination of Accumulated Rainfall and Hourly Rainfall". Rainfall history is typically created based on rainfall data and disaster records in the past 20 years. Then, the criteria of "accumulated rainfall" and "hourly rainfall" is defined by taking account of service years for each section, structure of road and slope, geography and geographical condition, etc.,


Start
- Observe of rainfall
- Accumulate its history
- Collect disaster history
- Store the data
Creation of rainfall history graph
Plot disaster data on rainfall history graph
Set criteria value
Operation

Source: JICA Expert Team

Figure 2-24 : Procedure for Criteria Setting

2.5.6 Observation and Accumulation of Rainfall Data

Road operators observe rainfall by meteorological observation facility placed along roadways and certainly save them. The rainfall data is preferable to be saved in a data format which enables to invert into MS-EXCEL format so that road operator can create a figure of rainfall history easily when setting and updating the criteria value. In addition, it is necessary to adopt a storage medium with the multiplicity of use.

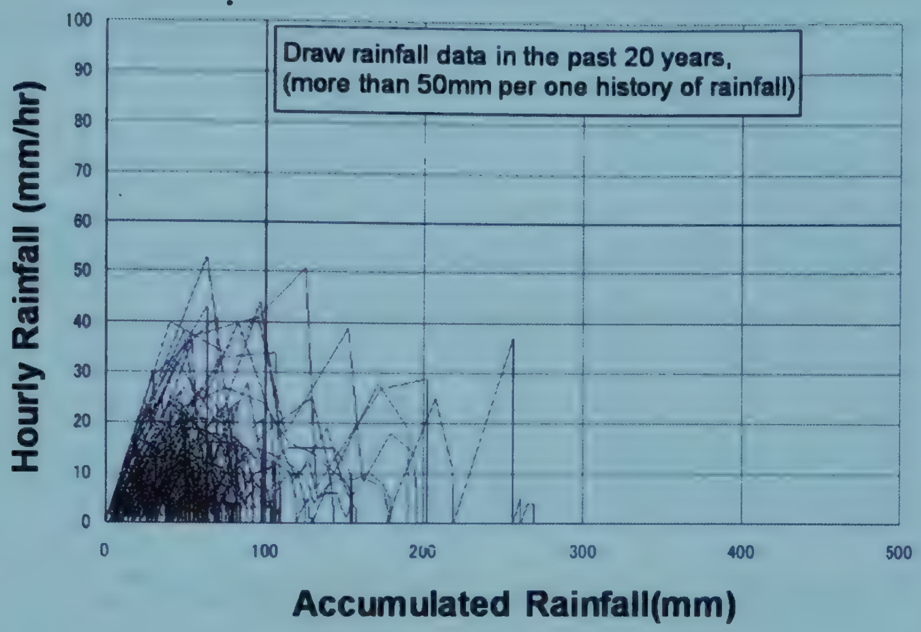
2.5.7 Collection and Accumulation of Disaster Information

Road operators need to set a criteria value by paying attention to rainfall characteristics and disaster history in each stretch and section. In this regard, it is necessary to collect and save data about past disaster information as listed below:

1) Time and date of the disaster (the time of occurrence and detection is especially important information to grasp the amount of rain at the time disaster occurred).
2) Location of disaster (section, inbound/outbound line, chainage, etc.)
3) Form of damage (collapse, rock fall, landslide, debris flow, etc.)
4) The scale of damage (soil volume, area, extension, number of a slope, slope protection type, etc.)
5) Information of traffic regulation (Influence on main lane, regulation, regulation method, regulation time, etc.)
6) Weather/rainfall information (pattern of rainfall (by the typhoon, stationary front in the rainy season, etc.), location of weather observation stations, rainfall data (accumulated rainfall, hourly rainfall, etc.). As for rainfall data, the data collected approx. 2 days prior to the disaster occurrence is required.)
7) Others (information on damage to vehicle traffic, road facilities, etc.)

2.5.8 Creation of Rainfall History Figure

In this process, each rainfall data is plotted with a polygonal line in the figure, where accumulated rainfall and hourly rainfall are on the horizontal and vertical axis, respectively. By plotting the history of rainfall over the past 20 years, it enables to show rainfall characteristic at concerned observation points (See Figure 2-25). The rainfall history figure shall be created by using rainfall data approx. in the past 20 years at relevant observation points in each section. It is preferable to use data actually obtained at weather stations along roadways. Before sufficient observation data is accumulated, however, data from meteorological agencies neighboring relevant stretch can be adapted.



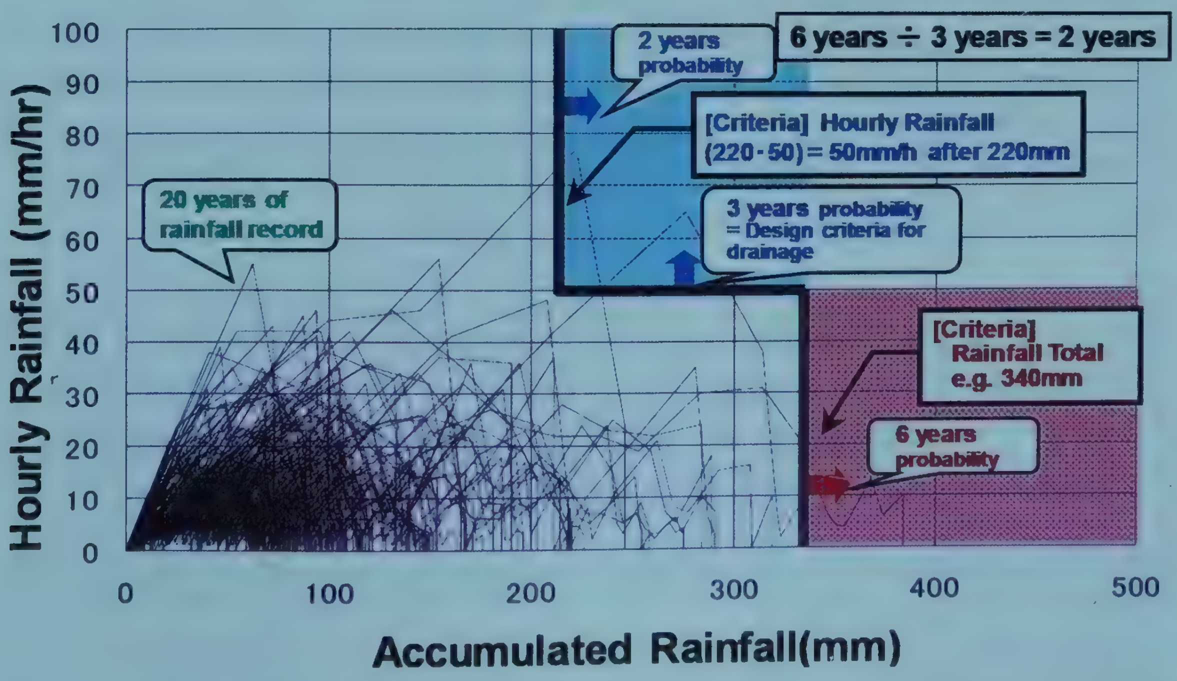
Source: JICA Expert Team

Figure 2-25: Figure of Rainfall History

2.5.9 Setting Criteria Value

By using the figure of rainfall history mentioned in the previous section, two criteria values shall be determined, which are “Accumulated Rainfall” and “Hourly Rainfall”.

“Hourly Rainfall” is the criteria value defined by the combination of accumulated rainfall and hourly rainfall as of then. For example, “Hourly Rainfall (220 · 50) shows that the accumulated rainfall is more than 220mm and in addition, hourly rainfall at the arbitrary time as of then is more than 50mm (See Figure 2-26)



Source: JICA Expert Team

Figure 2-26: Summary of Method of “Combination of Accumulated Rainfall and Hourly Rainfall”

"Probability method" shall be adapted for setting a criteria value, which allows road operators to apply the same approach according to the rainfall characteristic. The criteria value shall be set by each section, and the probability year of rainfall is set according to each section. As a general rule, rainfall amount which appears approx. every five or six years is recommended (i.e. probable rainfall of five or six years); however, the probability of rainfall of 10 or 20 years may be applied, depending on the importance of a stretch or characteristic of a section. The following points are required to be considered when setting criteria values:

- In-service period, rainfall experience, disaster history, scale/influence of damage, the structure of road (embankment/cut ratio, structure ratio), slope structure (slope type, slope form, etc.), geography/geological condition, etc.
- If there is a disaster history in a target section, rainfall amount at the time of damage occurrence shall be plotted on a figure of rainfall history. Then, road operators shall determine whether the disaster history is to be reflected or not into a determined criteria value by taking account of scale/cause of each disaster, countermeasure after disaster occurrence, or rainfall experience.

2.5.10 Exempted Section for Setting Criteria Value

(1) Setting Exempted Section for Rainfall Criteria Value

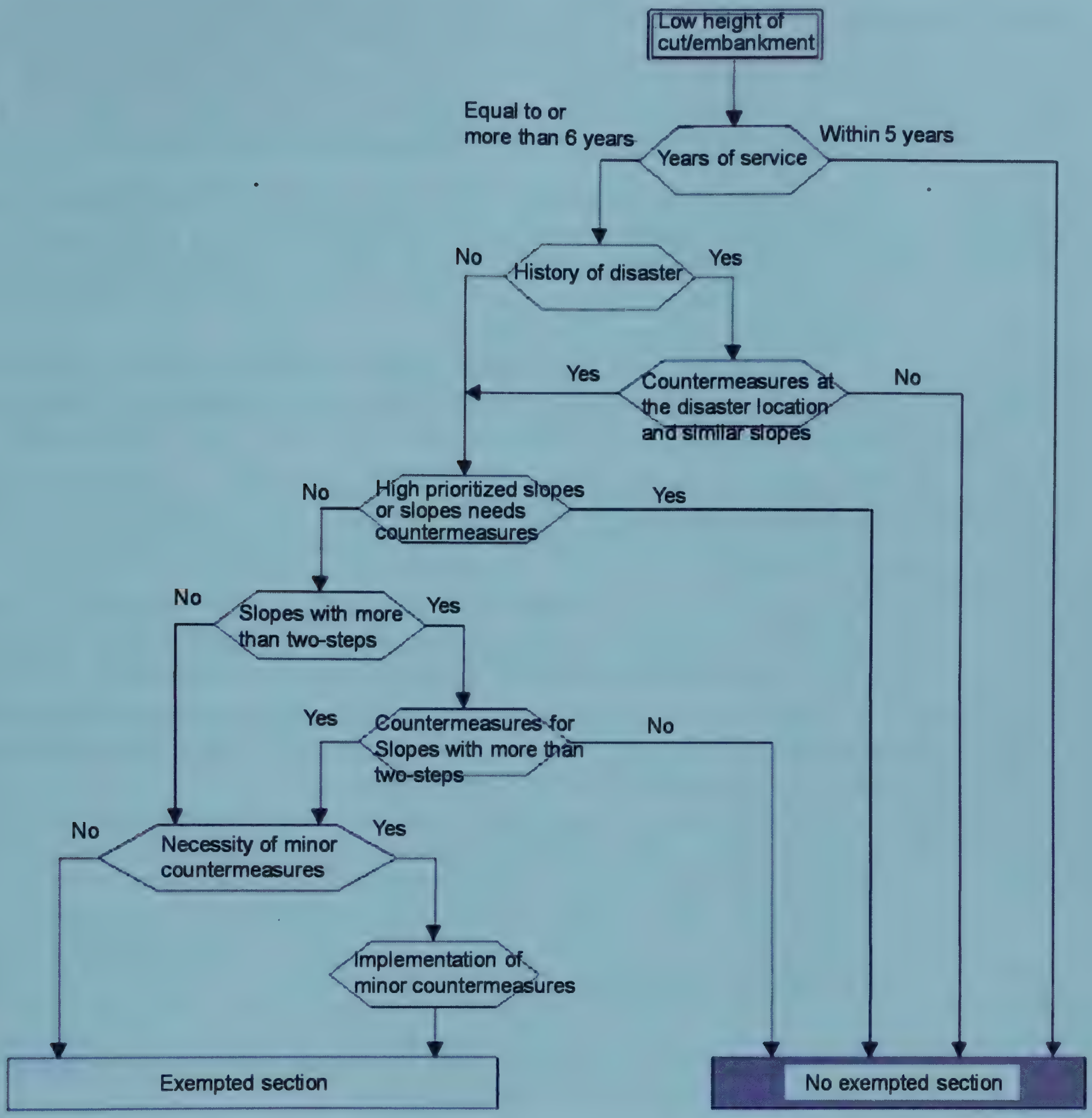
The road closure due to rainfall is basically conducted when a high risk of disaster is identified or disaster occurred; however, it requires to define the criteria value to close road before an event, which accurately prevents the third party damage. However, as road operators have proceeded to install slope protection works etc. in order to secure safe and smooth traffic, it has led to a high rate of having no disaster at the time of road closure. In recent years, the development of highways and expressways networks has been progressed and played a major role to connect areas to areas. In this regard, it is highly needed to minimize the time of road closure and thus the influence on the road users or social cause by the road closure.

Under these circumstances, the causal relationship among collapse form of a slope, inspection result, countermeasure, etc. were further analyzed. Based on the analysis, it was decided that criteria value of road closure can be exempted for a section where no past disasters and adequate countermeasure works are conducted and where disaster is expected to have very limited damage to main traffic because of structure type (bridge, low height of embankment/ cut). As for the section where disaster may occur outside of right-of-way, it requires to consider separately.

In a section where the criteria value of road closure is exempted, however, it is still necessary to monitor the condition of highways in real-time for 24-hour by road patrol or meteorological stations placed along the highways. When the risk of road damage or abnormality is detected by road patrol, immediate response and road closure/traffic regulation are required to tackle the situation.

(2) Procedure of Setting Exempted Section for Criteria Setting

For decision flowchart of exempted section for criteria set, it shall be selected based on Figure 2-27 below, which includes the factors of inspection record, disaster record, and hinterland along highways.


Low height of cut/embankment
Equal to or more than 6 years
Years of service
Within 5 years
No
History of disaster
Yes
Yes
Countermeasures at the disaster location and similar slopes
No
No
High prioritized slopes or slopes needs countermeasures
Yes
No
Slopes with more than two-steps
Yes
Yes
Countermeasures for Slopes with more than two-steps
No
No
Necessity of minor countermeasures
Yes
Implementation of minor countermeasures
Exempted section
No exempted section

Source: JICA Expert Team

Figure 2-27: Decision flowchart of exempted section for criteria setting

(3) Section of Low Height of Cut / Embankment

A section of the low height of cut/embankment is regarded as an exempted section of the criteria value of rainfall. Definition of a section of the low height of cut/embankment is "most of the road structures are composed of bridge, tunnel, and one-step of embankment/slope, where disaster causes very limited damage on the main line even if it occurs." Definition of the one-step slope is as follows:

- "One-step slope" means that a slope is one-step and its height is less than 10m.
- "More than two-step slope" means that a slope is equal to and/or more than two steps regardless of height. Nevertheless, in case the height of a slope is more than 10m, it is classified into "More than two-step slope"

In regard to the determination of an exempted section for criteria value, road operators in charge shall confirm the condition of individual slope between each interchange (including the history of disaster, inspection result, measurement status, geological condition, etc.) following the flowchart shown in Figure 2-27. In addition, a factor of accessibility of the main line from connecting roads shall be also taken into account.

- Low height cut/embankment is just a definition to extract potential sections for exemption from the criteria value of rainfall. Thus, a road operator in charge shall thoroughly confirm individual slope conditions (history of disaster, inspection result, measurement status, geological condition, etc.) and then judge on the concept of safe failure
- In case a section with low height cut/embankment is newly opened or capacity augmented (i.e. 4-6 laning) within five years, exemption of criteria value shall not be performed.
- In case a slope where a disaster occurred in the past exists or geography/geological condition is similar to the disaster-hit slope exists, and such slope is not protected by structures, exemption of criteria value shall not be performed.
- The slope protection includes crib works, retaining wall mechanic, reinforcement insertion work, anchor work, etc.; however, it does NOT include vegetation slope, etc. in its definition.
- In case inspection results suggest the necessity of slop protection or the existence of slops of failure or damage, a section with such inspection results shall not be exempted from criteria value
- In case a section includes more than two-step slopes partially, exemption of criteria value shall not be performed unless slope protection measures by structure are performed for all such slopes.
- In case there is a possibility of minor collapse such as bounding stone (pebble) which may disturb traffic on the main line, a road operator in charge shall consider the necessity simple measurement work.

2.5.11 The procedure of Criteria Value for Newly Opened Section and Capacity Augmented Section (4/6-laning section)

Newly-opened section, including the newly 4/6-laning section, is typically more susceptible to rainfall damage. Japanese experience shows that rainfall damages occurred in a new section within five years of its opening account for approx. 50% of all damages. Additionally, newly opened sections suffer damages at the time of the lower amount of accumulated rainfall by approx. 50mm in comparison with those of old sections which passed more than 6 years from their openings. Taking account of these facts, criteria value on a newly opened section should be set more strictly in order to secure traffic safety.

2.5.12 The setting of Interim Criteria Value

In case a section suffers rainfall damage such as a landslide and emergency countermeasures are completed, a lower criteria value than an original regular criteria value shall be applied, for the time being, considering that durability of road structure, such as slope, has been weakened.

(1) When the meteorological bureau announces that the warning standard of heavy rains and local flooding gets lower, an interim criteria value shall be determined

by a full understanding of announcement by meteorological agency, emergency recovery, damage condition, surrounding condition, etc.

(2) Except for item (1), an interim criteria value shall be set based on “rainfall amount at the time of disaster” by a full understanding of emergency recovery, damage condition, surrounding condition, etc.

(3) In either case above, when a function of drainage system is not sufficiently secured, a road operator shall apply a lower criteria value (i.e. more strict criteria value) for hourly rainfall which is usually probability rainfall of approx. 3 years.

2.5.13 Time to Review and renew criteria value

A criteria value determined in the previous sections is not unchangeable but should be updated periodically. The time to review and renew a criteria value is as follows.

(1) When it is determined that approx. five years have passed since opening to the public or when the necessity arises due to abnormal weather etc.

(2) As for an existing stretch in service, a road operator shall review and renew by the experience of rainfall and/or disaster.

2.5.14 Operation Level for Disaster Prevention Action

The Standard of operation level should be determined according to a criteria value of rainfall on each stretch or warning standard of the meteorological observatory in a relevant area. For setting an operation level, a road operator should take it into account to secure sufficient time to conduct prompt actions in case of the occurrence of damage. After the announcement of the emergency level, it is required to perform inspection or patrol to identify potential damage before it happens, a countermeasure for road closure when reaching the criteria value of traffic regulation.

At the same time, it requires to determine disaster prevention system and disaster information communicating activity also for a stretch under construction. The purpose is to prevent the occurrence of damage before it happens, or to remove the influence immediately, when a disaster may occur or pose a threat to the third parties.

Also, it is necessary to set up an emergency contact system and collaboration with adjacent road operators, when support and assistance are asked for by such operators.

2.5.15 Procedure for Setting Operation Level

(1) In case of setting an operation level by a factor of accumulated rainfall, criteria shall be set so that a road operator can take sufficient measures for road closure, with paying due attention to the “hourly rainfall” criteria value of road closure.

(2) There is another methodology to set an operation level by referring to an official announcement of warning by the meteorological agency in relevant areas.

2.5.16 Classification of Operation Level

An operation level is typically classified into four levels, which are “caution”, “alert”, “emergency”, and “urgent”. The detail of each level is specified from (1) to (4) below. Nevertheless, in case a large-scale disaster occurs in other areas outside jurisdiction of a road operator, an adequate level and system shall be selected according to damage conditions or a request from other road operators so that such road operators can arrange necessary support to other operators.

(1) Caution Level

On "caution level", a road operator collects and shares weather information, road condition information, etc., and monitors changes in that information. An operation office structures the system that can collect information of weather, road condition, etc., and conducts special patrolling by patrol teams. As for highways under construction, a similar system shall be developed accordingly.

(2) Alert Level

"Alert level" is basically adapted if disaster possibly occurs. An operation office that operates national highways in service collects information of weather, road condition, etc., and conducts special patrols 24 hours a day. Simultaneously, it conducts reduction of speed limit (e.g. decreasing the speed limit from 80km/h to 50km/h) by adjusting with related-authority, such as traffic police.

(3) Emergency Level

"Emergency level" is adapted when the measurement of rainfall exceeds the criteria value described in Section 2.5, or a minor disaster occurs. An operation office controlling highways in service collects information of the weather, road condition, etc., and conducts special patrol 24 hours a day. They also conduct road closure by adjusting with related-authority, such as traffic police. Moreover, sufficient human resources become necessary to respond to inquiries about a road closure from road users, police, adjacent road operators, and to coordinate with traffic control teams.

(4) Urgent Level

"Urgent system" is adopted when disaster associated with a road closure occurred on highways in service, which leads to significant influence on the society. In addition to the resources arranged on the "Emergency level", workforce and human resources are required to conduct immediate recovery of disaster according to the condition of the disaster.

2.5.17 Organization, Responsibility Allocation, and Constituent Members for Operation Levels

Table 2-9 shows typical organization, allocation of responsibility, and constituent members on each operation level. An operation team leader shall conduct supervise and direct, sum up and monitor operation level, and can change organization, allocation of responsibility, and constitute members, as necessary. Especially, in case a hike of operation level continues for a long period of time, the team leader should secure appropriate rotations of staff dealing with relevant tasks. A deputy team leader may be appointed to support a team leader. During the absence of a team leader, he or she shall perform the assigned task on behalf of the team leader.

Table 2-9: Organization on each operation level, allocation of responsibility, and constituent members of an operation office on highways in service

Constituent member		Allocation of responsibility	Constituent member			
			Caution level	Alert level	Emergency level	Urgent level
Operation team leader		1 Supervision and direction on each operation level. Decision-making on overall procedures and relevant detailed items.	○	○	○	○
Coordination team		1 Adjustment for overall communication 2 Total information collection 3 Liaison and coordination with regional headquarters, other relative authorities, etc.		○	○	○
General affairs/PR		1 Safety confirmation of the employees and their families 2 Disaster emergency measures of the operation office facilities 3 Awareness of injured people and their care 4 Securing food, accommodation, and vehicles 5 PR			○	○
Traffic condition confirmation team	Traffic condition confirmation team	1 Total adjustment for the consultation with the police 2 Road and traffic control 3 Information provision (Other than Website)		○	○	○
	Patrol team	1 Road and traffic control 2 Inspection and summary of results	○	○	○	○
Road recovery team	Road recovery team	1 Recovery of road 2 Consideration on backup human resources and equipment required for disaster emergency recovery 3 Consideration of alternative routes			○	○
	Facility recovery team	1 Road facility recovery 2 Consideration on backup human resources and equipment required for disaster emergency recovery 3 Adjustment with communication companies			○	○
Sales team		1 Collecting toll fee 2 Customer service at toll gates or rest areas 3 Emergency measures at toll gates, rest areas, etc.		△	○	○

Source: JICA Expert Team

2.5.18 Standard on Issuance and Release of Operation Levels

Standard on issuance and release of operation levels shall be determined based on the criteria value specified in Section 2.5.9, traffic regulation criteria, and degree of influence on the society.

An operation team leader is responsible for issuing, releasing, and changing an operation level. In case the "Urgent level" is adapted, the emergency response center shall be immediately organized. Similarly, in case the "Emergency level" is adapted, the emergency response center shall be organized, as necessary. An operation team leader works ahead of the emergency response center on an urgent level (or emergency level), and he or she shall designate a deputy head of the emergency response center.

2.5.19 Traffic Regulation and Road Closure

(1) Conducting Road Closure and Regulation

The criteria for conducting road traffic regulation shall be determined by each road section, along with criteria for operation level described in previous sections.

In order to conduct and release road closure and regulation smoothly and accurately, it requires to consult with relative authorities in advance. As for handling emergency vehicles and other required issues, it shall be consulted beforehand with police, local government, and other related authorities such as other road operators.

When conducting a road traffic regulation, a road operator shall organize necessary consultation with police and adjacent road operators. Nevertheless, in case it is confirmed that road closure is unavoidable for an emergency case, a road operator can conduct road closure and report the detail and reason immediately after such action.

(2) The procedure of Road Closure

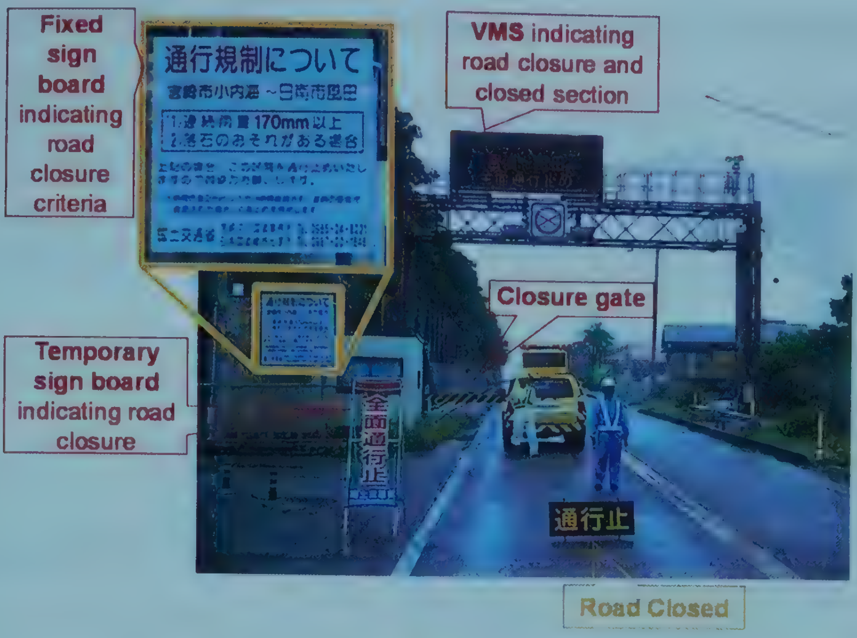
When a road operator conducts a road closure, they need to provide travelling vehicles with such information promptly by VMS and broadcasting facilities along highways and to take necessary measures so that road users do not enter into concerned sections.

When a road operator conducts road closure due to heavy rainfall, they should instruct road users to take appropriate action by such as immediately leaving a concerned section or refraining from entering into a concerned section.

(3) Installation of Closure Gate

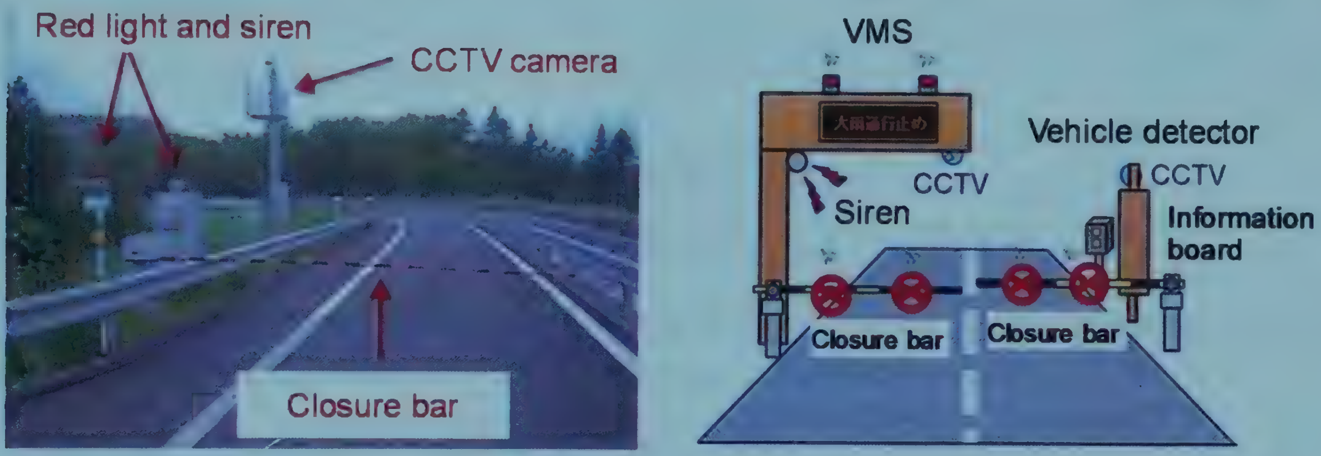
In case a proper road closure is to be performed against unpredictable short local concentrated torrential rain, it is sometimes a challenge to organize an appropriate system because preparing time for human resources and equipment on site is extremely limited.

Because of this, it is recommended to adopt a manual closure gate or automatic (remote-controlled) closure gate for prompt closure of a concerned section, as shown in Figure 2-28 and Figure 2-29, respectively.


Fixed sign board indicating road closure criteria
通行規制について
1.連続雨量170mm以上
2.落石のおそれがある場合
VMS indicating road closure and closed section
Closure gate
Temporary sign board indicating road closure
全面通行止
通行止
Road Closed

[6]

Figure 2-28: Image of Manual Closure Gate on Highway without Access Control


Red light and siren
CCTV camera
Closure bar
VMS
Vehicle detector
CCTV
Siren
CCTV
Information board
Closure bar
Closure bar

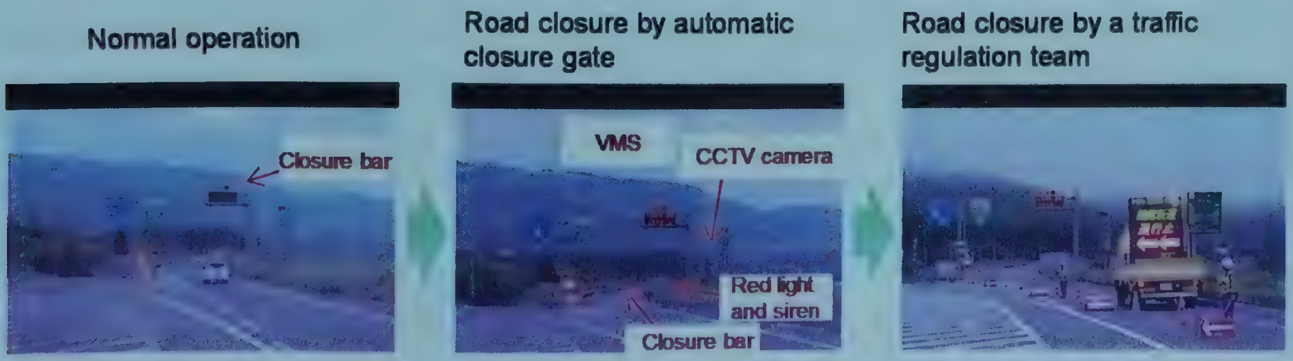
Interchange of access controlled highway

Highway without access control

[6]

Figure 2-29: Image of Automatic (Remote-Controlled) Closure Gate

When closing a road section due to disaster, accident, or heavy rainfall, a road operator should check the safety of road/traffic condition by CCTV camera, etc., and then lower the closure gate bar by remote control (See Figure 2-30). Although this automatic closure gate is considered as a supplemental method before a traffic regulation team arrives at the gate, it would be very effective to perform road closure promptly, which can tackle unexpected local torrential rain.


Normal operation
Closure bar
Road closure by automatic closure gate
VMS
CCTV camera
Red light and siren
Closure bar
Road closure by a traffic regulation team

[6]

Figure 2-30: Flow of road closure by automatic (remote-controlled) closure gate

2.5.20 Release of Traffic Regulation and Road Closure

(1) Criteria of Releasing Traffic Regulation, Road Closure, etc.

A road operator can release road closure, after conducting inspection and confirming to meet the following criteria from 1) to 4) below. It is also necessary to consult traffic police as well as adjacent road operators, and give a notification to them.

1) When a disaster has already occurred, emergency recovery measure at the location is mostly completed and it is judged that no secondary disaster occurs.
2) Inspection from moving vehicles is conducted to release road closure, and no abnormality is confirmed.
3) At the completion of vehicle inspection, it is judged that rainfall will stop by the short-term weather forecast.
4) Before releasing road closure, no abnormality is confirmed.

(2) Procedures of Release of Road Closure

The following items from 1) to 5) specify release procedures in case accumulated rainfall exceeds the criteria value.

1) When damage has already occurred, emergency recovery measure is mostly completed at the location where the damage occurred, and it is necessary to judge that no secondary disaster occurs for passing vehicles after road closure is released.
2) Inspection from moving vehicles shall be started to release road closure, when it is judged that rainfall is coming to an end without a forecast of rainfall (less than 2mm/hr), by short-range precipitation forecast.
3) Inspection to release a road closure is conducted by vehicle inspection. During the nighttime, except for a section where safety is sufficiently secured by lighting facilities, an inspection needs to wait until daybreak when there becomes enough light to confirm the safety.
4) It is necessary that no abnormality is confirmed on vehicle inspection to release road closure. Moreover, the amount of rainfall is judged to be less than 2mm/hr by short-range precipitation forecast.
5) When all conditions from 1) to 4) are fulfilled, road closure can be released.

Nevertheless, it requires to confirm that no abnormality is identified before releasing the road closure.

(3) Release Procedures When Hourly Rainfall Exceeds Criteria Value

1) When damage has already occurred, emergency recovery measure is mostly completed at the location where the damage occurred, and it is necessary to judge that no secondary disaster occurs for passing vehicles after road closure is released.
2) Inspection from moving vehicles shall be started to release road closure when it is judged from rainfall information that rainfall is below the criteria value of hourly rainfall and that it will not exceed the criteria value again.
3) Inspection to release the road closure is conducted by vehicle inspection. During the nighttime, except for a section where safety is sufficiently secured by

lighting facilities, an inspection needs to wait until daybreak when there becomes enough light to confirm the safety.

4) It is necessary that no abnormality is confirmed on vehicle inspection on item 3) above.

When all conditions from 1) to 4) are fulfilled, road closure can be released. Nevertheless, it requires to confirm that no abnormality is identified before releasing the road closure.

(4) Procedure to Release Road Closure

Although road closure is released based on the procedures specified above, it does not mean that safety after the release is 100% guaranteed. Therefore, a road operator shall keep the emergency level until no rain is confirmed for at least 6 hours (until the reset) onward after releasing road closure. In addition, an inspection of "inspection critical spots" shall be conducted according to the up-to-date site situation.

2.5.21 Disaster Inspection

This section describes required items for disaster inspection when abnormal weather, such as heavy rainfall and strong wind, is predicted or occurred. Disaster inspection aims to grasp the damage situation of road users as well as road and roadside conditions.

(1) Advance Preparation of Disaster Inspection

1) Organization and management of required materials

It is necessary to prepare the following materials on a daily basis, which are utilized to conduct damage emergency measures.

- Drawings of the plan, cross-section, longitudinal profile, detailed design of structures, etc.
- Aerial photography
- Relevant handbooks, guidelines, and manuals
- Inspection reports conducted regularly
- Inspection route map, etc.

2) Organization and management of inspection tools

The following items shall be referred for the preparation of inspection tools.

- Required tools for inspection: portable transceiver, mobile phone (with the camera or satellite-based, as necessary), camera (digital camera, video camera, etc.), convex, measuring tape, pole, inspection hammer, binocular, flashlight, blackboard, stepladder, projector, etc.
- Required equipment for emergency measures: shovel, arrow board, rubber cone, flag, smoke candle, etc.
- Other related equipment: helmet, work clothes, safety shoes, rain appeal, dust mask, protection against cold, extra battery and charging kit required for inspection, etc.

3) Preparation of inspection data sheet

The data sheet for inspection shall be created considering the usability when bringing it to the site. Inspectors should always have a necessary number of sheets with them.

4) Selection of inspection route

As for structure inspection, such as bridge and disaster-prone areas outside the right-of-way, it is necessary to approach such inspection locations outside of the right-of-way. In order to conduct a prompt and smooth inspection at the time of the disaster, an adequate inspection route to the following spots shall be identified in advance. Moreover, it is preferable to identify multiple routes, taking account of a possible situation when some of the routes can be devastated or congested which makes a road operator difficult to approach by the routes.

- Route for the disaster-prone area outside the right-of-way, or prioritized inspection spots
- Route for each bridge
- Route for each IC
- Route for inspection of roadside, etc.

5) Training of disaster inspection

Training of disaster inspection should be performed periodically so that concerned engineers can conduct disaster inspection smoothly, which includes:

- Training to use a portable transceiver, mobile phone, etc.
- Training to communicate with an operation office by using the emergency phone
- Training to use the video camera, digital camera, etc.
- Training to operate patrol vehicles (siren, loudspeaker, searchlight, vehicle-installed VMS, etc.)
- Training to organize simple lane regulation (as an emergency measure)
- Confirmation of inspection routes

6) Disaster prone areas outside the right-of-way

A road operator shall coordinate with a relevant administrator in charge of a disaster-prone area so that necessary collaboration is ensured for prevention measures.

(2) Conducting Inspection for Abnormal Weather

1) Category and purpose

Category and purpose for the inspection of abnormal weather are listed in Table 2-10 below:

Table 2-10: Category and Purpose of Abnormal Weather

Category	Purpose
Road patrol inspection	- When abnormal weather present - To grasp the circumstances of road users, and the sign of disaster on the road and its surrounded area as well as the presence of disaster in order to judge if raise of operation level is necessary or not and if traffic regulation/closure is necessary or not
Condition grasping inspection	- After conducting road closure - To grasp the damage condition which obstructs passing vehicle or sign of disaster
Road closure release inspection	- At the time of judging to release or continue road closure - To confirm if no obstacles exist and if no issues lead to the obstacle, and if there is no risk of secondary disaster
Emergency recovery inspection	- When the sign of disaster or disaster is confirmed. - To collect necessary information in order to develop plans for emergency recovery, etc.

Source: JICA Expert Team

2) Time, inspection target, method, and allocation of inspectors

Table 2-11 specifies the time, inspection target, method, and allocation of inspectors for abnormal weather inspection.

Table 2-11: Time, Target, Method, and Allocation of Inspectors for Abnormal Weather Inspection

Category	Start of time	Target	Method	Allocation of inspectors
Road patrol inspection	As necessary, depending on weather condition	- Primarily on the main line - Around the main line, when the sign of disaster or deformation is identified, by observation on foot	- Primarily inspection from moving vehicle - Observation on foot, as necessary	- Basically, one (1) team consists of more than 2 persons including an engineer - Observation on foot shall be conducted by an engineer
Condition grasping inspection	When road closure is conducted	- On the main line	- Condition grasping inspection	
Road closure release inspection	When judging release of road closure may be conducted	- Primarily on the main line - Around the main line, when the sign of disaster or deformation is identified, by observation on foot	- Primarily inspection from moving vehicle - Observation on foot, as necessary	
		- Prioritized spots for inspection - Disaster prone areas outside the right-of-way	- Primarily observation on foot	
Emergency recovery inspection	When emergency recovery inspection is considered necessary	- The spots where condition grasping inspection identified that emergency recovery needs to be conducted	- Primarily observation on foot	

Source: JICA Expert Team

3) Identification of disaster-prone areas outside the right-of-way

A road operator shall identify disaster-prone areas outside its right-of-way as far as possible in advance. Disaster-prone area includes area which may pose a risk to right-of-way at the time of disaster occurrence, including loose rocks and bounding stones which have the possibility of falling from the outside right-of-way, and areas where debris flow or slope failure is concerned.

4) Identification of prioritized inspection spots

A road operator shall identify prioritized inspection spots (slope, etc.) in advance, based on the past disaster history and inspection/investigation at usual condition. For this purpose, the following points should be taken into account.

i) Understand the condition of each slope sufficiently, and make an overall evaluation for the following items from ii) to vii), which are indicators of the high possibility of collapse due to rainfall
ii) Place a particular emphasis on the past inspection result
iii) Slopes with disaster record
A slope or similar slopes with disaster record or deformation record
iv) Spots where countermeasure or monitoring is necessary
A slope, etc. where past inspection judged that monitoring or countermeasures are required
v) Slopes where a special slope protection work is installed
A slope where special slope protection work (ground anchoring, restraining pile, catchment well) or a slope with continuous monitoring
vi) Slopes and their hinterlands where destabilizing potential exist
Destabilizing potential includes fault, fracture zone, intrusive rock, landslide area, rock fall, geography modification
vii) Geological condition with collapsibility factor

(3) Record and Evaluation of Disaster Inspection

1) Record of disaster inspection

During abnormal weather inspection, inspectors shall record abnormality, driving conditions, and damage situation. These records are effective to carry out disaster emergency measures promptly. Moreover, inspectors shall record relevant information necessary for the development of emergency recovery and newly found deformation or damage during emergency recovery inspection.

2) Evaluation of disaster inspection

As for the section where damage is identified by inspectors, a road operation office makes a judgement of continuing or releasing a traffic regulation based on the classification in Table 2-12 below, paying due attention to weather conditions and characteristics of the stretch.

Table 2-12: Classification of Traffic Regulation

Requires road closure
A road closure is unnecessary but requires some form of traffic regulation
Enables to release traffic regulation

Source: JICA Expert Team

In addition, the following judgement shall be performed based on results of condition grasping inspection, etc.

- Determine the necessity of request for support from another office, branch office
- Extract priority spots for emergency recovery inspection
- Determine change of operation levels at an operation office, branch office, headquarter

(4) Points to Note during Disaster Inspection

1) During disaster inspection, inspectors shall contact their operation office in every section by communication tool, such as radio, cellular phone, emergency phone, regardless of the occurrence of damage. Nevertheless, if they find an emergency situation, they shall contact their office each time and receive instruction from the office. Moreover, at the time when inspectors identify a disaster, they shall report a recapitulative damage situation immediately, and take photos of damage by mobile phone and send them to the operation office to consider possible recovery methods promptly.

   [Items which requires emergency report]

   - When inspectors find damage on the road users
   - When inspectors observe weather conditions leading to an obstacle for driving the vehicle or identify damage on the road condition
   - When inspectors identify tilted or fallen road accessories (e.g. lighting, sign, etc.)
   - When inspectors have difficulties in continuing a vehicle inspection

2) When inspectors find a road user suffering from a disaster during their inspection, life-saving has the utmost priority.
3) At the time of the disaster, inspectors shall provide appropriate measures and perform prompt disaster inspection, taking due attention to the scale of the disaster, time of occurrence, weather condition, and road situation.
4) For grasping damage situation, a road operator shall effectively utilize information from traffic offices, road users, a resident living along the stretch, road user service facilities.
5) During night-time, inspection shall be basically performed from the moving vehicle, because lower visibility can make an inspection on foot dangerous. When deformation is confirmed, inspection on foot is conducted as necessary, after the safety of the inspector and weather condition is fully confirmed.
6) Landslide occurs with some time lag after rainfall. Thus, inspectors need to pay attention during daily inspection even if abnormal weather is suspended or finished.

2.5.22 Securing Temporary Road Function

(1) Emergency Recovery

When large damage occurs on the road in service and its surrounding area, a road operator shall try to prevent further damage on the road and put the highest priority to secure at least one-lane traffic for the passage of emergency vehicles by very immediate measures of crushed stone or sandbags put on the collapse of a road or the difference in level.

(2) Urgent Recovery

When a disaster occurs on the road in service, prompt recovery shall be conducted in order to secure road traffic and prevent further damage. In a section where road closure is conducted, a road operator shall recover at least a single lane per each ~~of~~ inbound/outbound direction or two lanes per either inbound or outbound in the stretch where inbound and outbound lanes are divided. In a section where inbound and outbound lanes are not divided, a single lane shall be recovered and secured.

As for conducting urgent recovery of the stretch in service, it shall adopt the fastest method according to damage condition. In case a disaster may pose a risk or cause influence on the third party, a road operator shall conduct necessary work to remove the influence immediately.

(3) Removal of Obstacles

Dirt, timber, and workpiece that may become an obstacle for passage of traffic shall be removed immediately on a stretch in service. In case it is difficult to secure any lane for passage of emergency vehicles due to an accident vehicle or leaving the vehicle, and it is confirmed as an emergency, a road operator shall remove obstacles of such vehicles in close coordination with relevant authorities.

2.5.23 Preparation for Future Disaster

(1) Stock and Procurement of Equipment

An operation office shall prepare its stock and procurement system on a daily basis so that a road operator can secure necessary equipment and resources immediately at the time of disaster to handle emergency traffic. Basically, a road operator shall stock equipment and resources which deemed frequently used.

(2) Well-equipped Emergency Response Center

An operation office shall strive to facilitate emergency response center and communication equipment required for smooth and quick action of emergency measures. Meeting rooms at an operation office are utilized for this purpose.

(3) Securement of Safety

A building of an operation office shall have sufficient earthquake resistance. If a seismic diagnosis identifies the necessity of seismic strengthening work, its road operator shall take necessary measures.

(4) Installation of Power Generation Facility

A road operator shall be equipped with a power generator in order to secure emergency power at the facility which is required for activities at the emergency center. Additionally, periodic inspection shall be performed to maintain its function at the time of usual operation. For preparing continuous operation of power generator, a road operator shall basically stock fuel equivalent to three days at a minimum on a daily basis, with checking the quality of fuel regularly.

(5) The stock of Food and Drinking Water, etc.

A road operator shall stock food and drinking water equivalent to three days-activity at minimum for employees as well as other goods necessary for daily life.

(6) Disaster Drill

An operation office shall conduct a disaster drill once per year in close cooperation with relevant authorities, in an area where a large-scale disaster is predicted. The disaster drill shall handle training of distribution of relevant information, initial response, and disaster emergency measures. The following items from 1) to 11) are major actions on a disaster drill, which shall be conducted practically:

1) Distributing of disaster occurrence information
2) Requesting operation office personnel to gather as emergency response staffs
3) Establishing and operating of emergency response center
4) Securing members dedicated to disaster emergency measures, and developing cooperation framework with relevant authorities
5) Preparation and arrangement of stand-by members, equipment, etc. after the disaster
6) PR of disaster information
7) Collecting information related to the road condition and its communication at the time of disaster occurrence
8) Road traffic measures
9) Emergency transportation measures
10) Countermeasures related to road facility
11) Development of emergency recovery plan

2.5.24 PR Activity

(1) PR Activity at the Time of Disaster Occurrence

A road operator shall provide information proactively to road users, etc. through a roadside facility providing traffic information (e.g. VMS, highway radio), internet, mass media, etc. A road operator shall also share the latest information with staff at a customer service center, toll plazas, and rest areas where all inquiries about road information are directed.

When providing information to mass media, a road operator shall pay careful attention to the precision of the information by such as establishing a framework of double-checking.

(2) PR Activity at the Time of Normal Situation

Through PR activities related to disaster prevention, a road operator may regularly provide road users with necessary information on actions taken at the time of disaster occurrence by using existing facilities and media, including the following:

1) Internet ·
2) Publications and videos
3) Notification by leaflet, brochure, poster
4) Banner, vertical banner, sign
5) Radio facility for broadcasting in the tunnel
6) Loud speaker facility at the rest area
7) Any other PR activities deemed effective

2.6 Control of Overloaded and Oversized Vehicles

2.6.1 A framework of Regulating Violation Vehicles

Operation on mountainous highways are roughly divided into two types, i.e. 1) Operation by BOT mode under concessionaires on a road-widening/development project, and 2) Operation directly conducted by road administrators such as state PWD on EPC or HAM mode. Considering efficiency and reality for the actual implementation of regulating violation vehicles, this chapter aims to describe fundamental policy about planning, design, and operation measures against violating overloaded and oversized vehicles, which is mainly conducted by concessionaires in road widening/development projects. The following four approaches are basically considered as countermeasures, which are;

1) Making U-turn (No entry to the highway)

As a general rule, make violating vehicles take U-turn at a toll plaza or relevant locations after passing through the locations on highways, which is an entry point of the highway, and then make the vehicles leave the highway to the access road from the exit gate(s).

2) Leaving highway from dedicated exit rampway(s)

If an interchange and/or a toll barrier, where it is difficult to make road users U-turn due to heavy traffic on as well as it is not so much difficult to provide a dedicated exit rampway(s) at the left side of the traffic lane(s) on the highway, make the violating vehicles leave the highway by driving toward the dedicated exit rampway(s) leading to outside the highway at the interchange or toll plaza after passing the entrance gate(s).

3) Load reduction

Make/guide violating vehicles move to the designated area and reduce their freight to meet within certain weight limitations for vehicles of road transportation. For the reduced freight, drivers of the violating vehicles will take the responsibility for the reduced freight and need to take proper action(s) to collect them as soon as possible.

4) Specifying the interchange to leave the highway

In case of a toll barrier where it is difficult to make a U-turn as well as to construct dedicated exit rampway(s), specify where to leave the highway (e.g. next interchange, etc.) and make violating vehicles leave.

In considering the operation method of above 1) to 4) for the regulation of violating vehicles, careful attentions need to be paid as follows;

1) Because of the current program for the vehicle inspection, maintenance and registration, it is difficult to identify each vehicle owner and/or driver (information on each owner is linked to the information on each vehicle registration at the time of purchasing a new car, while it is not for a used car).
2) In spite of introducing a system to pay a fine (penalty, challan) for violation (oversize, overload), some drivers cannot pay due to economic limitations.
3) If violating vehicles are permitted to enter without reducing their freight by imposing a fine, it causes a negative effect to the traffic and the highway such as overload on highway structures, reducing traffic safety, and/or increase in environmental load.
4) If freight is reduced at the specified place(s), the reduced freight may not be properly taken (collected) by its owner.

Considering the above points, the regulation method on violating vehicles shall be adopted taking into consideration the measures not to make violating vehicles enter the highway, that is to say, the operation methods focusing on 1) and 2) above.

As for preventive measures for violating vehicles to enter the highway, in addition, create a framework to impose predetermined penalties and fines depending on the type and degree of violation, which is disclosed to road users by putting up signs in front of each toll gate. As described above, however, a fine is collected when violating vehicles are determined because the drivers cannot be identified based on the information on the vehicle registration.

2.6.2 Operation Method according to Toll Collection System

The regulation method of violating vehicles shall be designed in consideration of the toll collection method and system, as shown in Table 2-13.

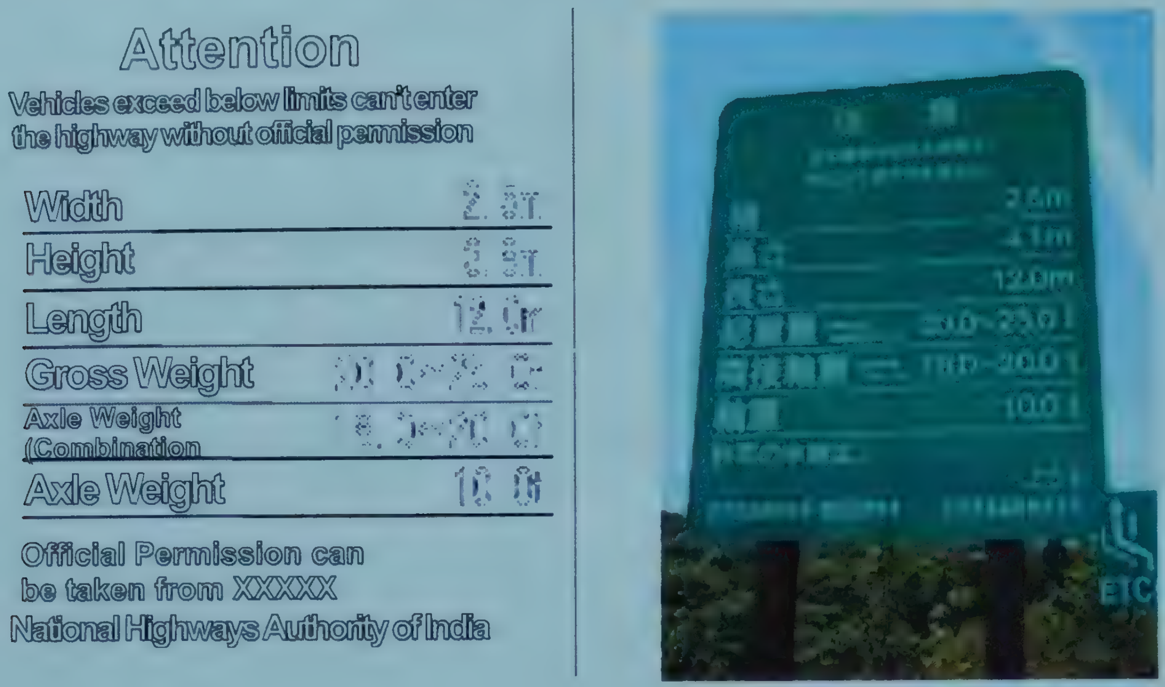
Table 2-13: Location for Regulation and Penalty Charge of Violating Vehicles According to Toll Collection System

Particulars	Location for Regulation and Penalty Charge of Violating Vehicles	
	Fixed-Rate Toll Collection	Distance-Based Toll Collection
Arrangement of toll gate/barrier	Toll barrier on the highway	Toll barrier on the highway and toll gate at the interchange
The location where regulating violating vehicle	Each toll barrier on the highway	Each toll barrier on the highway and each toll gate at the interchange
A location where the penalty is charged	Each toll barrier on the highway	Toll barrier on the highway and each toll gate at the entrance of the interchange
Remarks	--	Assumed fixed penalty charge regardless of the driving distance

Source: JICA Expert Team

2.6.3 Warning Sign for Over-loaded / Over-sized Vehicles

The criteria values of weight, height, width, etc. of a vehicle which can use a highway shall be informed to road users before entering the highway. The warning signs shall be provided to appropriate locations, i.e. 1) entry and exit of a highway, 2) intersections, 3) toll gates/booths, 4) wayside amenities, etc., as shown in Figure 2-31.


Attention
Vehicles exceed below limits can't enter the highway without official permission
Width 2.5m
Height 3.8m
Length 12.0m
Gross Weight 20.0~25.0t
Axle Weight (Combination 18.0~20.0t
Axle Weight 10.0t
Official Permission can be taken from XXXXX
National Highways Authority of India
2.5m
4.1m
12.0m
20.0~25.0t
18.0~20.0t
10.0t
ETC

Source: JICA Expert Team

Figure 2-31: Example of Warning Signs

2.6.4 Weigh-in-Motion

(1) Installation Location of Weigh-in-Motion

Weigh-in-Motions shall be installed according to "Clause 10.4.11 on IRC:SP:84-2014: Manual for Specifications and Standards for Four Laning of Highways through Public-Private Partnership" or "Clause 10.4.11 on IRC:SP:87-2013: Manual of Specification and Standards for Six Laning of Highways through Public-Private Partnership" as shown in Table 2-14. A Weigh-in-Motion system is used to measure the gross weight of vehicles with certain accuracy but not perfect, without stopping the flow of vehicles. Thus, the Weigh-in-Motion system shall be placed at locations where Weigh Bridge is also installed for adequate operation.

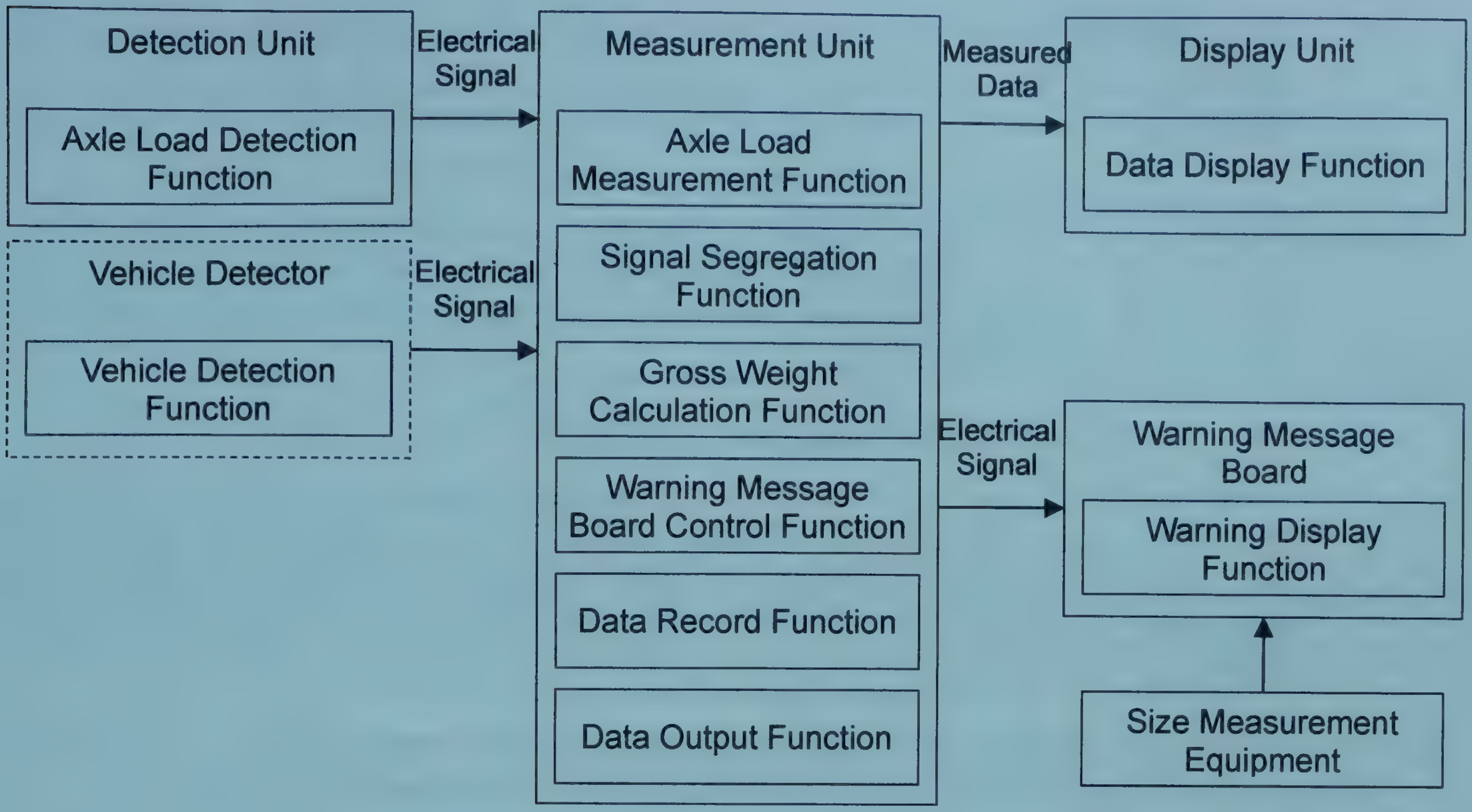
Table 2-14: Location of Weigh-in-Motion

References	Location of Weigh-in-Motion
IRC:SP:84-2014 IRC:SP:87-2013	10.4.11 Prevention of overloading Toll plaza location shall also be provided with a system for checking and preventing the overloading of vehicles at Toll Plaza. For this purpose, weigh-in-motion systems at approaches to each toll lane are to be installed.

[7] [8]

(2) Basic System Configuration of Weigh-in-Motion

Figure 2-32 shows the basic configuration of the Weigh-in-Motion (WIM) system. WIM system is constituted by 1) Detection unit, 2) Measurement unit, 3) Display unit and 4) Warning message board.


Detection Unit
Axle Load Detection Function
Electrical Signal
Vehicle Detector
Vehicle Detection Function
Electrical Signal
Measurement Unit
Axle Load Measurement Function
Signal Segregation Function
Gross Weight Calculation Function
Warning Message Board Control Function
Data Record Function
Data Output Function
Measured Data
Display Unit
Data Display Function
Electrical Signal
Warning Message Board
Warning Display Function
Size Measurement Equipment

Source: JICA Expert Team

Figure 2-32: WIM System Configuration"

1) Detection Unit

The function of a detection unit can be divided into two functions, i.e. 1) axle load detection function and 2) vehicle detection function. The detection unit is provided in the pavement at entrance gates of toll gates and emits electrical signals according to an acted load through vehicle tires when vehicles are passing on it. The Signal segregation function is used to sort electric signals of axels into each vehicle; therefore, this function of WIM system is not required to provide if vehicles can be detected and sorted by other facility(s).

2) Measurement Unit

The measurement unit is provided in a toll operation office with several functions, these are;

i) Axle Weight Measurement Function: Measure axle weight based on electrical signals according to an acted load through the detection unit.

ii) Signal Segregation Function: Sort electrical signals, i.e. measured axle weight into each vehicle detected by vehicle detector. If vehicles can be detected and sorted by other facility(s), it shall not be provided.

iii) Gross Weight Calculation Function: Calculate the gross weight of vehicles from measured and segregated axle weights.

iv) Warning Message Board Control Function: Emit control signal to display the warning on the warning message board after violating vehicles are passing on the detection unit, if it is required.

v) Data Record Function: Record measured data such as measured axle weight etc.

vi) Data Output Function: Output measured data such as measured axle weights etc.

3) Display Unit

The display unit is provided in an operation office and displays information such as measured axle weight data, etc. in the office.

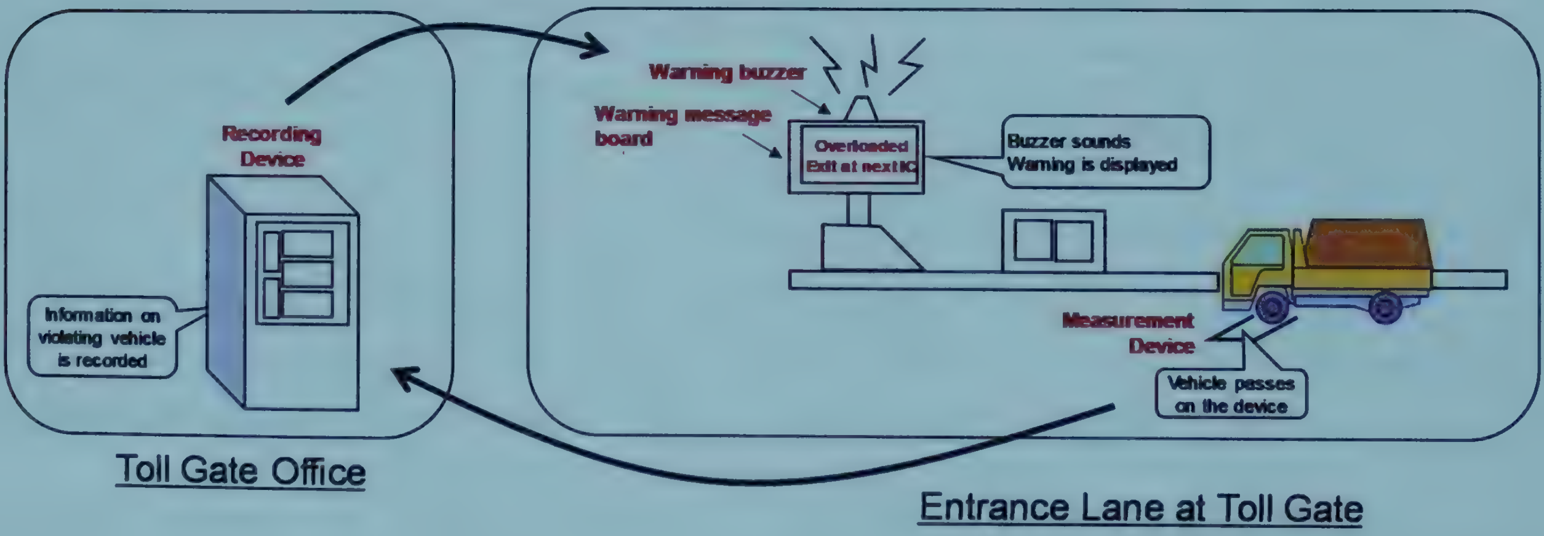
4) Warning Message Board

A warning message board shall be provided on an island of the toll booth at toll gates, and display warning messages to violate vehicles following the display control signals from the measurement unit.

(3) Basic Operation of Weigh-in-Motion

As shown in Figure 2-33 below, WIM system consists of 1) Measurement device, 2) Warning buzzer, 3) Warning message board, 4) Recording device such as the printer, etc., and 5) indicating device to accommodate electronic processing between the equipment 1) to 4). WIM system is operated following the basic procedure described below.

1) The measurement device detects a vehicle, measures axle weight, and estimates the gross weight of the vehicle when it passes on the device.
2) In case the axle weight of the vehicle exceeds the criteria value, Warning buzzer sounds and warning message such as "Overloaded, Exit from next Interchange" etc. is displayed on the Warning message board to make caution to a driver of violating vehicle (overloaded vehicle) in order to urge such a vehicle to leave the highway.
3) The measurement value of axle weight, as well as the date and time when a vehicle passes on the device, are recorded by the Recording device at a toll operation office timely.


Recording Device
Information on violating vehicle is recorded
Toll Gate Office
Warning buzzer
Warning message board
Overloaded Exit at next IC
Buzzer sounds Warning is displayed
Measurement Device
Vehicle passes on the device
Entrance Lane at Toll Gate

Source: JICA Expert Team

Figure 2-33: Basic Operation of WIM System

(4) Location of Measurement Unit and Display Unit

In principle, a measurement unit shall be provided in a toll operation office. A warning message board shall be provided on islands of toll booths at toll gates in order to display warnings to drivers of violating vehicles as well as to repress the violation. In addition, the display unit shall be placed in a toll operation office for surveillance and enforcement by overloaded / oversized control teams.

2.6.5 Requirements for Design and Construction of Weigh-in-Motion

(1) Detection Unit (Design)

i) The detection unit shall be robust electrically and mechanically.

ii) Sensors of the detection unit shall be protected against dust and water to satisfy the conditions to operate the unit properly.

iii) The detection unit shall have excellent corrosion resistance.

iv) The detection unit shall be designed in consideration of efficiency and easiness of maintenance (inspection, rehabilitation, replacement, etc.).

(2) Detection Unit (Construction)

i) The loading plate of the detection unit is preferred to be constructed at the same level with a surface of the pavement because the overall accuracy of measured data is strongly influenced by the flatness of the road surface around the detection unit (Preferably the level difference is less than 3mm).

ii) Electric cables are preferred to be placed at the higher side of the vertical gradient in order to avoid deterioration of cables by water entry and pooling.

iii) The detection unit is preferred to be placed and finished at the gentle gradient location in order to obtain overall accuracy of equipment specification, with avoiding the effect of the natural frequency of passing vehicles.

iv) In case of cold areas, especially snowy and ice regions, a detection unit is preferred to be designed to be able to set a heater, etc

v) In case the detection unit needs to be placed at the bridge/viaduct with steel slab section, it is highly recommended to be careful to construct and place flat location, i.e. to avoid the location such as the welding point, joint point, etc. of steel slab.

(3) Measurement Unit

i) The chassis of the measurement unit shall be robust electrically and mechanically.

ii) Enough seismic capacity shall be required for the chassis as well as the construction (placement) method of the measurement unit.

iii) The measurement unit shall be protected well against dust and water.

iv) Measurement units shall be designed in consideration of efficiency and easiness of maintenance (inspection, rehabilitation, replacement, etc.).

(4) Display Unit

i) The display unit shall be robust electrically and mechanically.

ii) Enough seismic capacity shall be required for the chassis as well as the construction (placement) method of the display unit.

iii) The display unit shall be protected well against dust and water.

iv) The display unit shall be designed in consideration of efficiency and easiness of maintenance (inspection, rehabilitation, replacement, etc.).

(5) Warning Message Board

i) The chassis of the warning message board shall be robust electrically and mechanically.

ii) Chassis and the display part of the warning message board shall be protected well against dust and water.

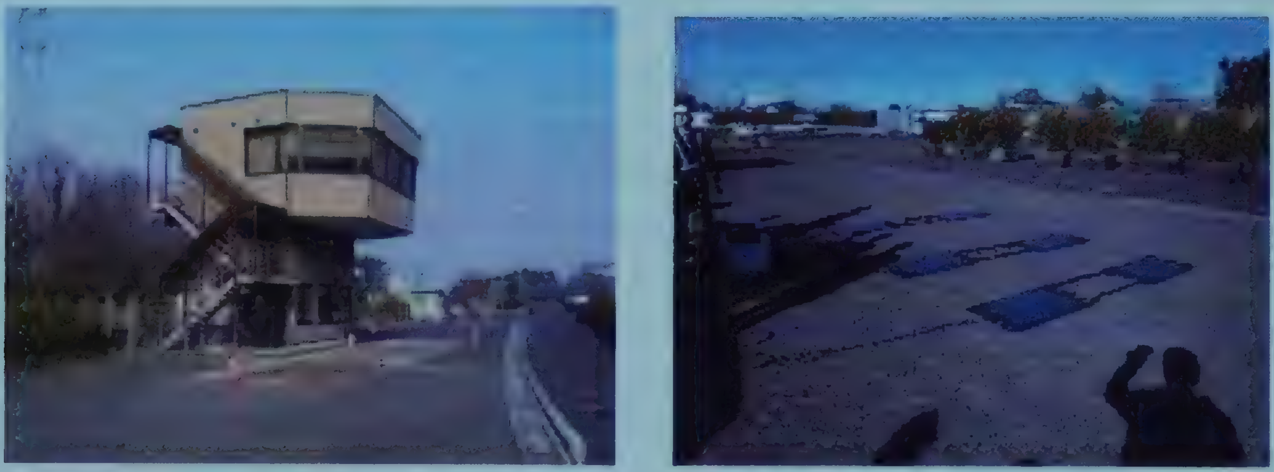
iii) The chassis of the warning message board shall have excellent corrosion resistance.

iv) The warning message board shall be designed in consideration of efficiency and easiness of maintenance (inspection, rehabilitation, replacement etc.).

2.6.6 Weigh Bridge

(1) Installation Location of Weigh Bridge

The main purposes of weigh bridge (vehicle weight scale) (Figure 2-34) are to accurately check the gross weight of violating vehicles identified by WIM. Installation of Weigh Bridge shall correspond to "Clause 10.4.11 on IRC:SP:84-2014: Manual for Specifications and Standards for Four Laning of Highways through Public-Private Partnership" or "Clause 10.4.11 on IRC:SP:87-2013: Manual of Specification and Standards for Six Laning of Highways through Public-Private Partnership" as shown in Table 2-15 and Figure 2-35.



Weigh Bridge

Weigh Bridge (Portable Type)

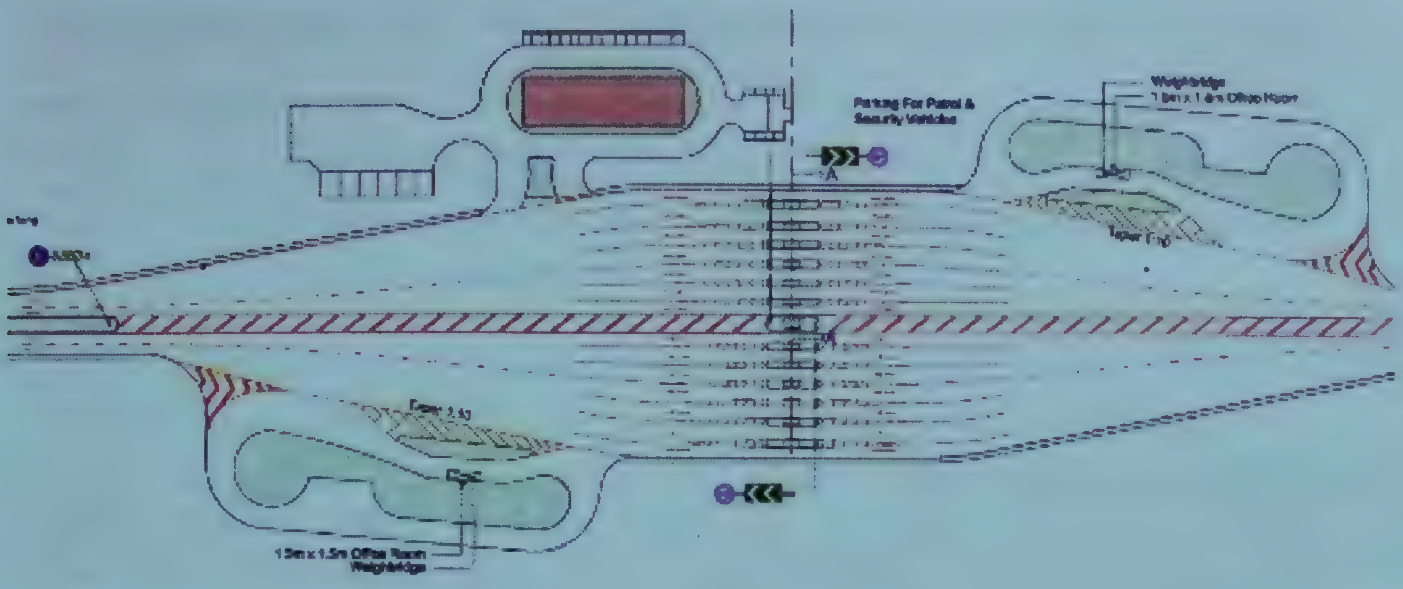
Source: JICA Expert Team

Figure 2-34: Weigh Bridge

Table 2-15: Location of Weigh Bridge

References	Location of Weigh Bridge
IRC:SP:84-2014 IRC:SP:87-2013	10.4.11 Prevention of overloading Separate space for static weigh bridge and area to hold off-loaded goods from overloaded vehicles shall be provided after the toll barriers for each direction of travel.

[7] [8]


Parking For Patrol & Security Vehicles
Weighbridge
1.5m x 1.5m Office Room
1.5m x 1.5m Office Room
Weighbridge

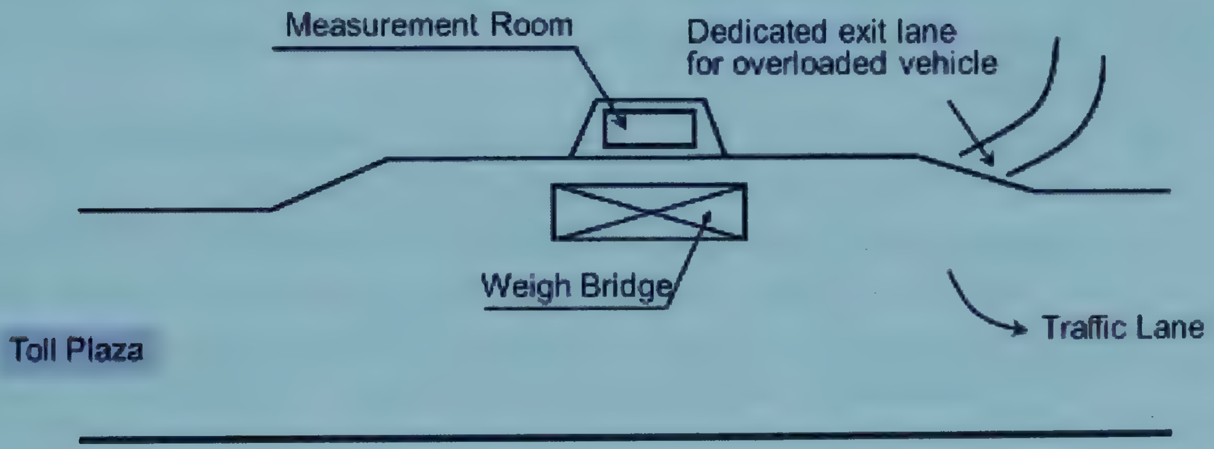
[7] [8]

Figure 2-35: Location of Weigh Bridge

(2) Arrangement of Weigh Bridge System

The major purposes of using weigh bridge are to measure the gross weight of violating (overloaded) vehicles precisely which is identified by WIM, and to give notice to drivers of overloaded vehicles when they refuse to accept the fact of overloading. Therefore, the weigh bridge shall be placed at the side of the left shoulder on a highway after passing through toll plazas/barriers as shown in Figure 2-36.

Measurement room (building) shall be planned and provided adjacent to a weigh bridge in consideration of the path of vehicles.

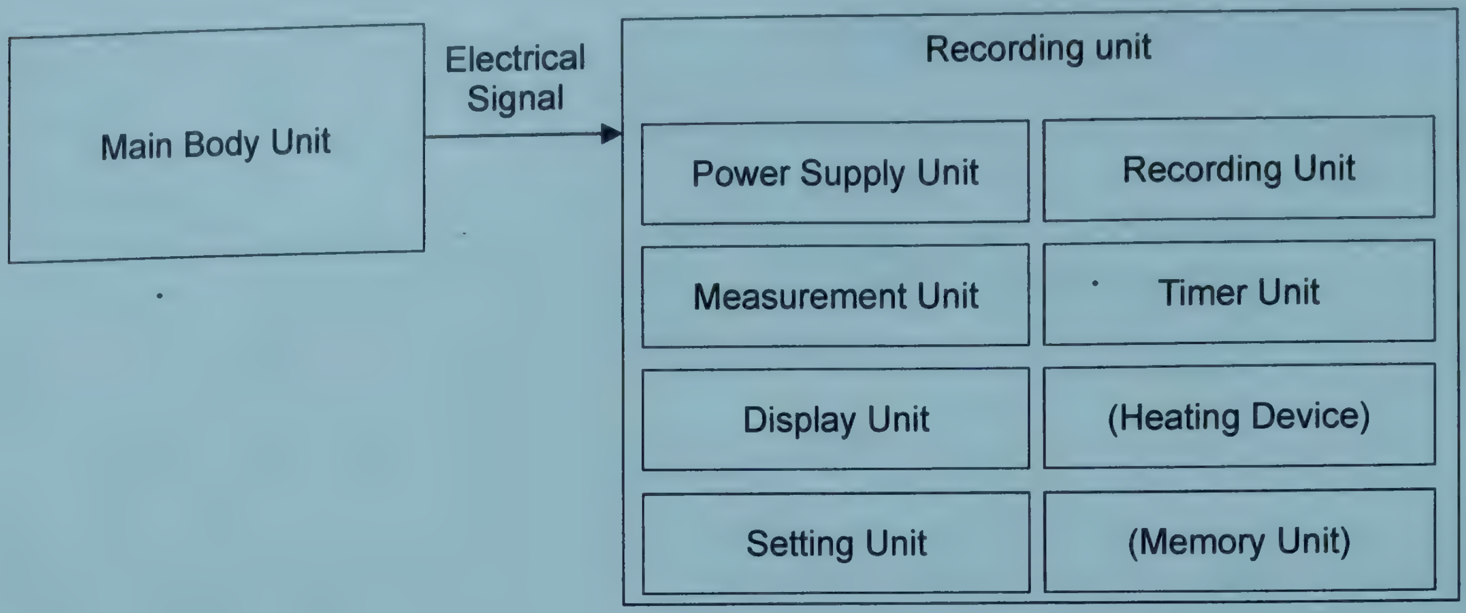

Measurement Room
Dedicated exit lane for overloaded vehicle
Weigh Bridge
Toll Plaza
Traffic Lane

[9]

Figure 2-36: Arrangement of Weigh Bridge

(3) System Constitution of Weigh Bridge

Figure 2-37 describes the basic configuration of the Weigh Bridge system. Weigh bridge system is constituted by 1) the Main body unit and 2) the Recording unit.



[9]

Figure 2-37: Weigh Bridge System Configuration

1) Main Body Unit

The main body unit consists of a Cover plate, Loading stage, Junction box, Load cell, etc., and emits electrical signals to the Recording unit after converting the measured weight data of vehicles into electrical signals by a load cell.

2) Recording Unit

The Recording unit is provided in the measurement room and consists of several units as shown below. The heating device and memory unit can be installed if it is required (optional).

- *Power Supply Unit:* Power unit supplies electricity for all equipment of weigh bridge.
- *Measurement Unit:* The measurement unit calculates the gross weight of vehicles based on the electrical signals from the load cell.
- *Display Unit:* The display unit shows the necessary information for enforcement of overloaded vehicles such as gross weight, date and time, etc. to the screen.
- *Setting Unit:* Setting unit is to input the necessary information for enforcement of overloaded vehicles such as type of vehicles, driver's and vehicle's information, etc.
- *Recording Unit:* Recording unit records measured and input data of measured vehicles.
- *Timer Unit:* Timer unit manages the date and time of weigh bridge system.
- *Heating Device:* The heating device keeps the temperature of the load cell to keep the accuracy of weigh bridge.
- *Memory Unit:* The memory unit can memorize the input data necessary for the measurement of vehicle weight.

(4) Requirements for Design and Construction of Weigh Bridge

1) Main Body Unit

- Cover plate, loading stage of the main body unit shall be fabricated by steel plate / shaped steel and shall have enough strength against the measurement of vehicles.
- The cover plate of the main body unit shall arrange properly, and unnecessary gaps shall not be made between cover plates.
- It shall be provided the device to avoid the rotation of cover plates.
- Load cell consists of sensor, strain gauge, and storage case and shall be protected well against dust and water.
- The sensor shall measure the weight over 20 tons.
- The junction box shall be attached on the loading stage and shall be protected well against dust and water.
- An anti-vibration device shall be equipped to the main body unit.
- The main body unit shall be placed not to act unbalanced load due to abrupt steering/slope because the weigh bridge (loading plate) is designed to use installing horizontally and measure the vehicle weight by longitudinal direction.

2) Recording Unit

- Enough seismic capacity shall be required for the chassis as well as the construction (placement) method of the recording unit.
- A heating device shall be required for anti-freezing of the load cell in a cold area and shall be attached to the load cell.
- The controller of the heating device shall be placed in the desktop panel and shall equip ELB (Earth Leakage Breaker) and automatic temperature controller.

2.6.7 Vehicle Height Meter

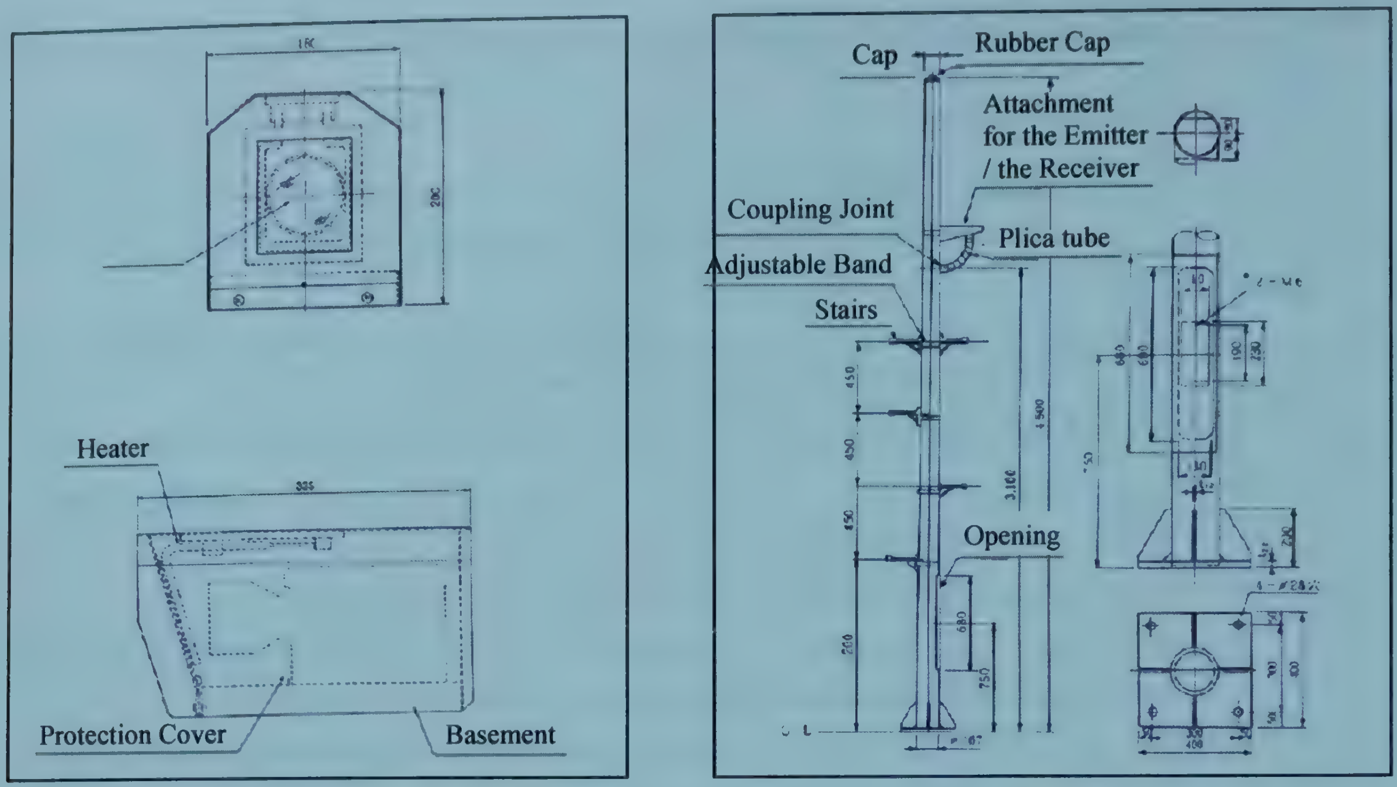
(1) Installation Location of Vehicle Height Meter

The vehicle height meter starts its operation when modulated infra-red light from the light-emitting device (the Emitter) to the light-receiving device (the Receiver) is blocked by some objects (e.g. over-height vehicles) exceeding the threshold height. Installation of the Vehicle Height Meter shall be therefore installed on both sides of islands of the toll booth, the Emitter is one side and the Receiver is opposite.

In case a vehicle height meter detects an over-height vehicle, a warning message to the violating vehicle is displayed automatically on a message sign board as shown in Figure 2-33.

(2) System Constitution of Vehicle Height Meter

Vehicle height meter consists of 1) Mother controller, 2) Sub controllers, 3) the Emitter, 4) the Receiver, and 5) Poles for the Emitter and the Receiver. Figure 2-38 shows images of the Emitter / the Receiver and the Poles.


Heater
Protection Cover
Basement
Cap
Rubber Cap
Attachment for the Emitter / the Receiver
Coupling Joint
Plica tube
Adjustable Band
Stairs
Opening

The Emitter / The Receiver

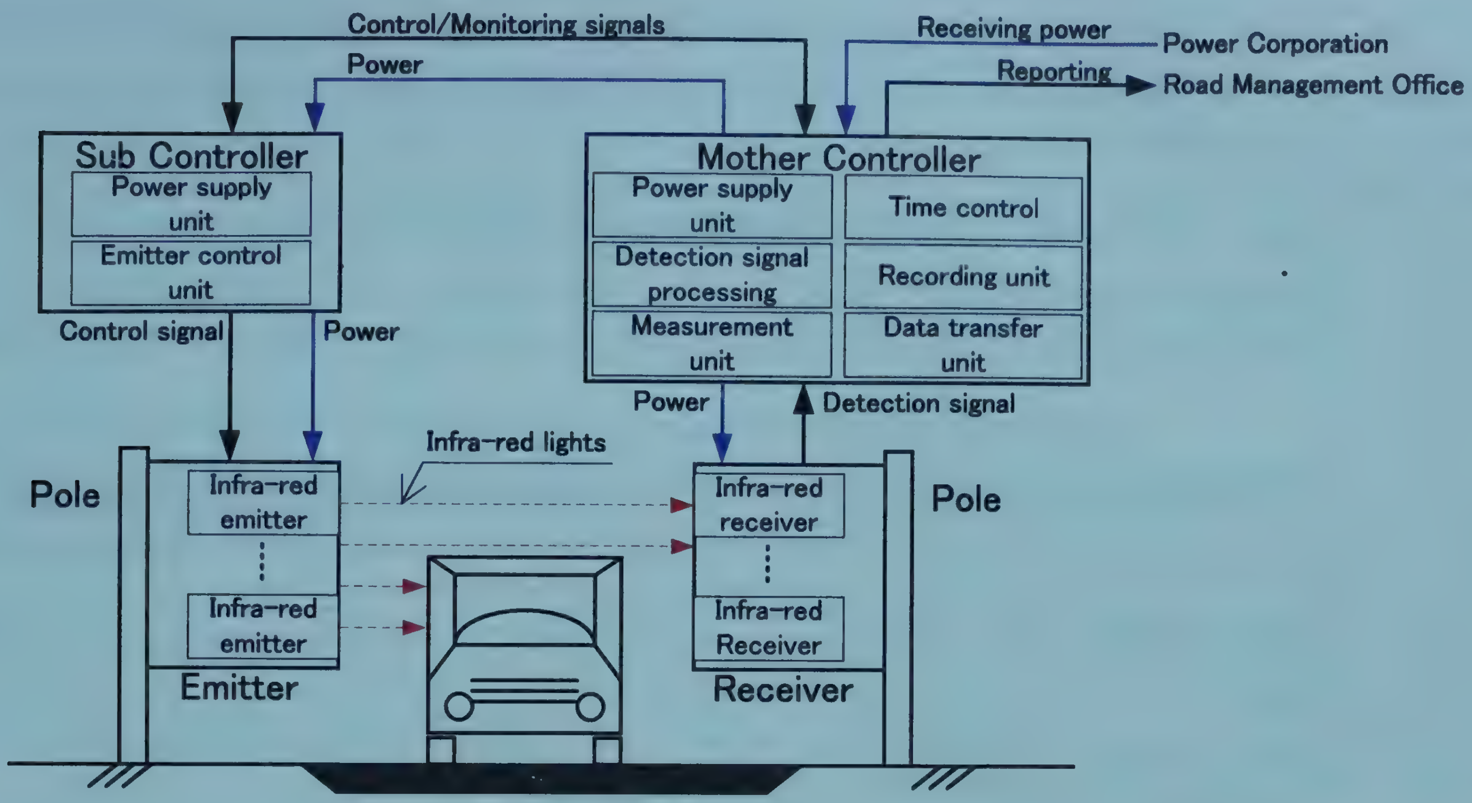
Pole

[9]

Figure 2-38: Emitter / Receiver and the Poles

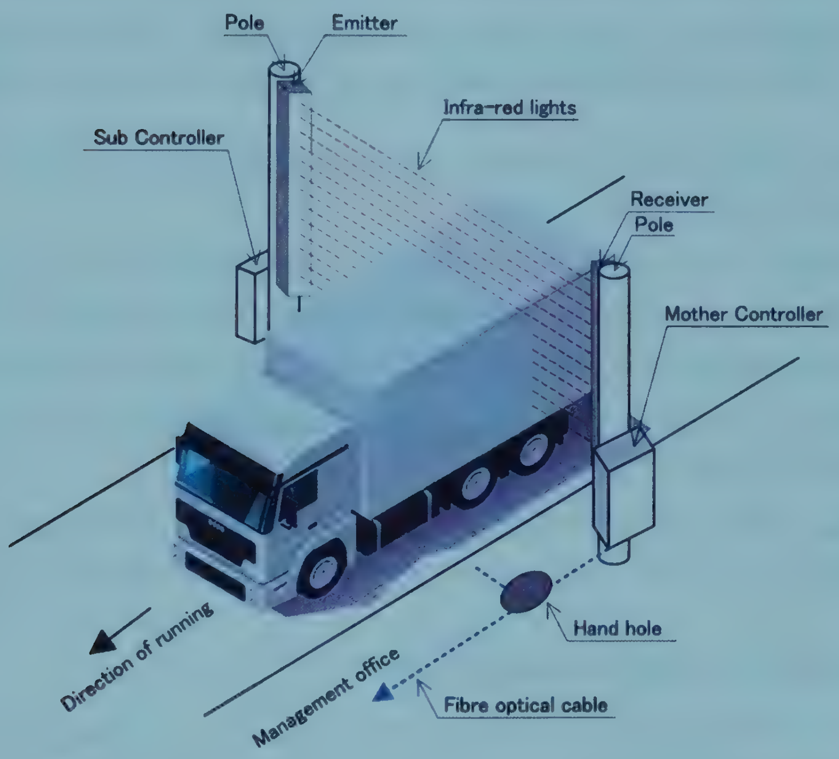
- *Mother Controller:* The mother controller outputs warnings based on detection signals from the Receiver.
- *Sub Controller:* Sub controller outputs warnings based on warning signals from the mother controller and outputs return signals to the mother controller.
- *The Emitter:* The emitter emits continuous pulse luminous flux with set frequency stably.
- *The Receiver:* The receiver receives infra-red light from the Emitter and emits detection signals to the mother controller when light is blocked.
- *Pole:* The Emitter and the Receiver are attached and supported by poles, and poles are placed at the islands of a toll booth. Stairs are preferably attached to poles to inspect the Emitter / Receiver.

Figure 2-39 and Figure 2-40 show images of a system configuration of a vehicle height meter.


Control/Monitoring signals
Power
Receiving power
Power Corporation
Reporting
Road Management Office
Sub Controller
Power supply unit
Emitter control unit
Mother Controller
Power supply unit
Time control
Detection signal processing
Recording unit
Measurement unit
Data transfer unit
Control signal
Power
Power
Detection signal
Infra-red lights
Pole
Infra-red emitter
Infra-red emitter
Emitter
Infra-red receiver
Infra-red Receiver
Receiver
Pole

Source: JICA Expert Team

Figure 2-39: System configuration of Vehicle Height Meter


Pole
Emitter
Infra-red lights
Sub Controller
Receiver
Pole
Mother Controller
Hand hole
Direction of running
Management office
Fibre optical cable

Source: JICA Expert Team

Figure 2-40: Bird's-eye view of Vehicle Height Meter

(3) Requirements for Design and Construction of Vehicle Height Meter

- The vehicle height meter system shall be robust electrically and mechanically.
- The vehicle height meter system shall be protected well against dust and water as well as insects.
- The vehicle height meter system shall be designed and fabricated in consideration of efficiency and easiness of maintenance (inspection, rehabilitation, replacement, etc.).
- Mother controller shall be united and installed in the measurement system.
- A heater shall be provided to the Emitter and the Receiver in a cold region.

- The Receiver shall be designed to avoid false detections by rain, snow, fog, etc.
- The Receiver shall equip some shields to avoid misoperation by the scattered light.

2.6.8 Constitution of Operation Team for Enforcement

Operation team shall be established for the regulation of violating vehicles. Table 2-16 shows the outline of staff and equipment as well as their roles and responsibilities.

Table 2-16: Operation Team of Regulation of Violating Vehicles

Staffs & Equipment	Roles and Responsibilities
Enforcement staff	A person engaged in regulation activities of violating vehicles. The activities are conducted by the team and a team leader shall be nominated in each team.
Operation leader	A person who controls regulation activities on-site, managing above enforcement staff.
Vehicle	A vehicle used for regulation activities of violating vehicles.
Wireless telephone	Portable wireless telephone device, transceiver, plug-in telephone, mobile phone (including smart phone), and emergency telephone.

Source: JICA Expert Team

2.6.9 Fundamental Attitude of Enforcement Personnel

An enforcement staff shall always comply with the following particulars with the utmost care and attention for safety and smooth traffic on highways.

- Always be precise in the manner and attempt not to provide unpleasant feelings to the road users.
- Always carry an alarm whistle, employee ID card, and writing utensils. Present employee ID card when asked by the road users or relevant authorities.
- Always kept the uniform neat and tidy, wore it appropriately.
- Always conduct prompt processing and operation of the regulatory activities of violating vehicles.
- Make effort to maintain and improve quickness and promptness, by doing stretching exercises, etc. before work, in order to safeguard their physical safety.

2.6.10 Safety of Enforcement Staff

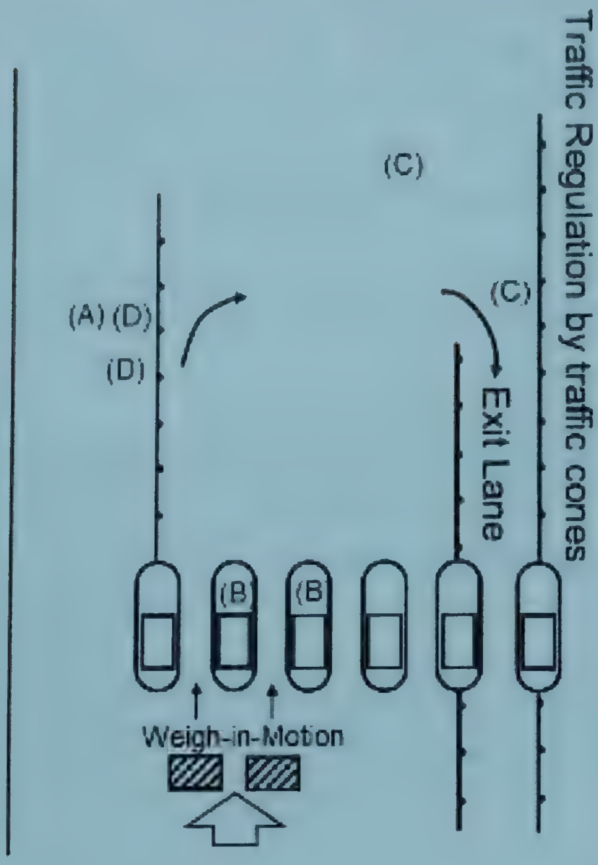
An enforcement staff(s) shall use red flag, etc. during daytime and light-emitting (e.g. LED type) traffic wand baton at night when making a vehicle stop temporarily or guiding a vehicle in order to conduct the regulation activities on a highway safely. Enforcement staff shall communicate by a transceiver, an alarm whistle, portable microphone, red flag, and light-emitting (e.g. LED) traffic wand baton, etc.

2.6.11 Validation of enforcement equipment

An enforcement staff(s) shall make sure if everything is working properly for fixed (such as weigh bridge etc.), or portable (such as mat-scale, etc.) enforcement equipment before implementing activities. As for the enforcement equipment which requires periodical inspection, a staff(s) shall also confirm expiration date of the equipment and record the result on a daily report.

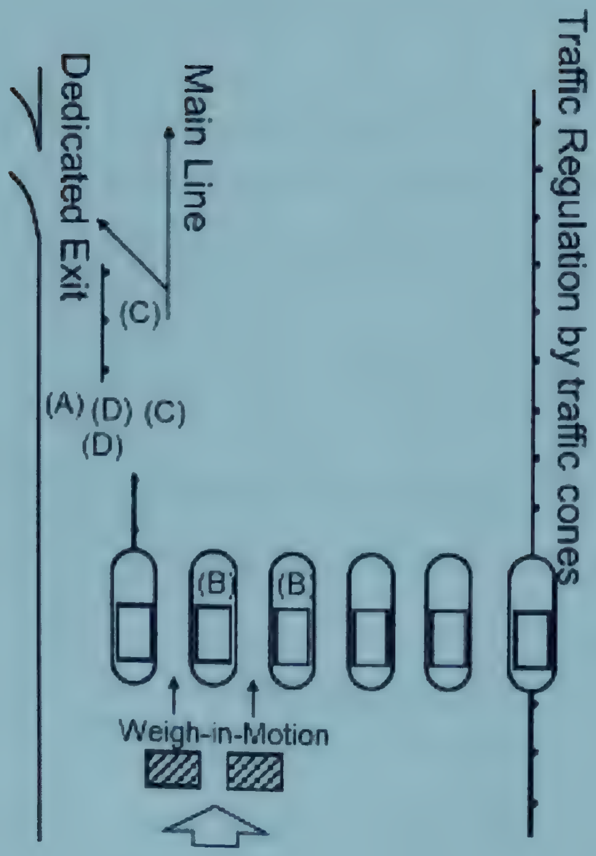
2.6.12 Arrangement of Enforcement Staffs

When regulating violating vehicles, enforcement staffs shall be typically arranged as shown in Figure 2-41 and Figure 2-42. When regulation is implemented in wayside amenities (rest areas), roles and responsibilities of each staff shall not be changed, and arrange the enforcement staff properly depending on the situation.



(A)	Leader (1 person)	Support other enforcement staff as needed as well as supervise all staff for traffic regulation/guidance of vehicles comprehensively.
(B)	Warning team (2 persons)	Basically, stay close to the booth and identify a violating vehicle and instruct to stop temporarily. When the guide team guides the violating vehicle, in addition, make a vehicle, enter the toll gate booth, stop temporarily in order to secure safety.
(C)	Guide team (2 persons)	Guide the violating vehicle toward the exit lanes or road shoulder where the traffic is unlikely affected, and give traffic directly to other road users as needed.
(D)	Measurement team (2 persons)	Investigate and record the violation content of violating vehicles, and count the number of violating vehicles. Also, persuade the driver who does not follow the instruction of making U-turn as well as correction of loading method. Report the driver who does not follow the instruction to the company and ask for backup.

(a) Making U-turn

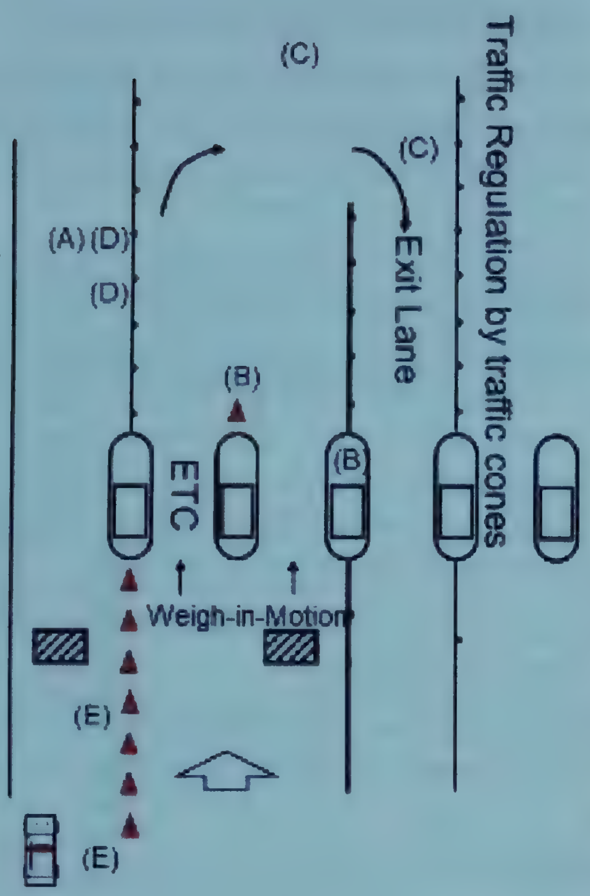


(A)	Leader (1 person)	Support other enforcement staff as needed as well as supervise all staff for traffic regulation/guidance of vehicles comprehensively.
(B)	Warning team (2 persons)	Basically, stay close to the booth and identify a violating vehicle and instruct to stop temporarily. When the guide team guides the violating vehicle, in addition, make a vehicle, enter the toll gate booth, stop temporarily in order to secure safety.
(C)	Guide team (2 persons)	Guide the violating vehicle toward the exit lanes or road shoulder where the traffic is unlikely affected, and give traffic directly to other road users as needed.
(D)	Measurement team (2 persons)	Investigate and record the violation content of violating vehicles, and count the number of violating vehicles. And persuade the driver who does not follow the instruction of leaving the highway as well as correction of loading method. Report the driver who does not follow the instruction to the company and ask for backup.

(b) Making Leave highway from the dedicated exit lane

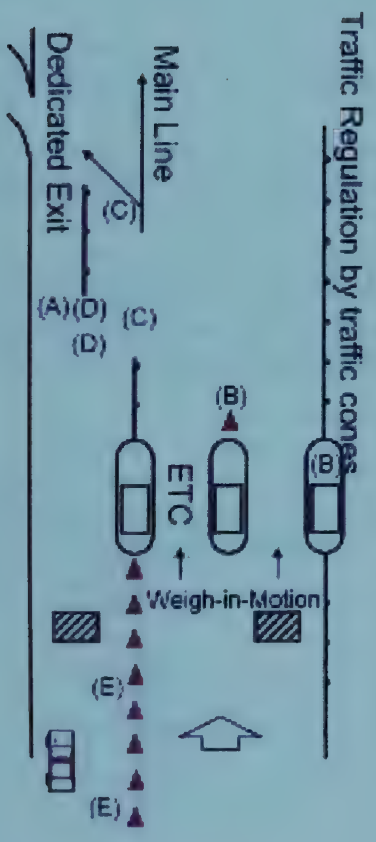
[10]

Figure 2-41: Standard Staff Arrangement (Regulation at non-ETC Lanes)



(A)	Leader (1 person)	Support other enforcement staff as needed as well as supervise all staff for traffic regulation/guidance of vehicles comprehensively.
(B)	Warning team (2 persons)	Basically, stay close to the booth and identify a violating vehicle and instruct to stop temporarily. When the guide team guides the violating vehicle, in addition, make a vehicle, entering the toll gate booth, stop temporarily in order to secure safety.
(C)	Guide team (2 persons)	Guide the violating vehicle toward the exit lanes or road shoulder where the traffic is unlikely affected, and give traffic direction to other road users as needed.
(D)	Measurement team (2 persons)	Investigate and record the violation content of violating vehicles, and count the number of violating vehicles. And persuade the driver who does not follow the instruction of making U-turn as well as correction of loading method. Report the driver who does not follow the instruction to the company and ask for backup.
(E)	Watching team (2 persons) *Arranged depending on site conditions.	Inform about the regulation to the entering vehicle to ETC lane and urge to reduce the speed. When a violating vehicle is found, report to the relevant teams. If necessary, make the violating vehicle stop temporarily in order to secure safety and instruct the driver to enter the toll booth slowly.

(a) Making a U-turn



(A)	Leader (1 person)	Support other enforcement staff as needed as well as supervise all staffs for traffic regulation/guidance of vehicles comprehensively.
(B)	Warning team (2 persons)	Basically, stay close to the booth and identify a violating vehicle and instruct to stop temporarily. When the guide team guides the violating vehicle, in addition, make a vehicle, enter the toll gate booth, stop temporarily in order to secure safety.
(C)	Guide team (2 persons)	Guide the violating vehicle toward the exit lanes or road shoulder where the traffic is unlikely affected, and give traffic direction to other road users as needed.
(D)	Measurement team (2 persons)	Investigate and record the violation content of violating vehicles, and count the number of violating vehicles. And persuade the driver who does not follow the instruction of leaving highway as well as correction of loading method. Report the driver who does not follow the instruction to the company and ask for backup.
(E)	Watching team (2 persons) *Arranged depending on site conditions.	Inform about the regulation to the entering vehicle to ETC lane and urge to reduce the speed. When a violating vehicle is found, report to the relevant teams. If necessary, make the violating vehicle stop temporarily in order to secure safety and instruct the driver to enter the toll booth slowly.

(b) Making Leave highway from the dedicated exit lane

[10]

Figure 2-42: Standard Staff Arrangement (Regulation at ETC Lanes)

2.6.13 Operation for Enforcement of Over-sized / Over-loaded Vehicles

When a vehicle, which is overloaded or oversized, entered a toll gate, enforcement staff shall ask for official permits for oversize / overload. The vehicle which is not officially permitted shall be regulated and operated in accordance with the measures in Table 2-17.

Table 2-17: Measures Taken for Violating Vehicles

	Items	Taken by	Measures Taken
1	Instruction to the vehicle with suspicious violation	Warning team	Give the instruction to the driver to stop the vehicle temporally and move to a safe place (road shoulder etc.), where the vehicle shall not disrupt the traffic, for the measurement of vehicle, when an overloaded/sized vehicle is found.
2	Move the vehicle to the designated area and report	Warning team	Move the suspected violating vehicle, and report the contents of the suspected violation to the leader.
3	Traffic regulation of temporary stopping for the vehicle entry	Warning team	Make a vehicle(s), enter the toll gate, stop temporarily by using an alarm whistle and red flag, etc., based on the instruction made by the leader.
4	Guide the violating vehicle to the designated area	Guide team	Guide the vehicle to the designated area and make it stop temporarily by using an alarm whistle and red flag, etc., based on the instruction made by the leader.
5	Instruction of deregulation of traffic	Leader	Instruct the deregulation of traffic to the warning team when safety on the highway is ensured, after making the violating vehicle move.
6	Re-open traffic for the temporarily stopped vehicles	Warning team	Reopen the traffic based on the instruction made by the leader.
7	Measurement and record	Measurement team	Measure and record the violating vehicle by using the regulation device (Weigh bridge etc.).
8	Issuance of warning/instruction letter	Measurement team	Explain the content of the violation to the driver, and issue a warning/instruction letter.
9	Report of leaving highway/making U-turn etc.	Measurement team	Report the leader about the measure taken to the violating vehicle leave, U-turn or unload, etc.
10	Guiding violating vehicle	Guide team	Make the vehicle leave or U-turn after promoting sufficient awareness by using an alarm whistle and red flag, etc. based on the instruction made by the leader. When making the vehicle unloaded, guide the violating vehicle to the designated area.
11	Traffic regulation of temporary stopping	Warning team	Instruct a vehicle(s) entering the toll gate to stop temporarily by using an alarm whistle and red flag, etc., in case of making the vehicle U-turn.

[10]

2.6.14 Operation for Enforcement of Improperly Loaded Vehicles

When a violating vehicle enters a toll gate, which is likely to fall unstable or unfixed load, enforcement staff shall take the measures in accordance with Table 2-18.

Table 2-18: Measures Taken for Improperly Loaded Vehicles

	Items	Taken by	Measures Taken
1	Instruction to the vehicle with suspicious violation	Warning team	Give the instruction to the driver to stop the vehicle temporally and move to a safe place (road shoulder etc.), where the vehicle shall not disrupt the traffic, for the confirmation of falling down prevention measures of the load or instruction of fixing / re-loading of the load, when an improperly loaded vehicle is found.
2	Move the vehicle to the designated area and report	Warning team	Move the suspected improperly loaded vehicle, and report the contents of the suspected violation to the leader.
3	Traffic regulation of temporary stopping for the vehicle entry	Warning team	Make a vehicle(s), enter the toll gate, stop temporarily by using an alarm whistle and red flag, etc., based on the instruction made by the leader.
4	Guide the violating vehicle to the designated area	Guide team	Guide the vehicle to the designated area and make it stop temporarily by using an alarm whistle and red flag, etc., based on the instruction made by the leader.
5	Instruction of deregulation of traffic	Leader	Instruct the deregulation of traffic to the warning team when safety on the highway is ensured, after making the improperly loaded vehicle move.
6	Re-open traffic for the temporarily stopped vehicles	Warning team	Reopen the traffic based on the instruction made by the leader.
7	Instruction of correcting loading method	Measurement team	Instruct correction if the load is required to be reloaded or pile over again, after loading investigation.
8	Issuance of warning/instruction letter	Measurement team	Explain the content of the violation to the driver, and issue a warning/instruction letter.
9	Report of leaving highway/making U-turn etc.	Measurement team	Report the leader about the measure taken to the improperly loaded vehicle leave, U-turn or unload, etc.
10	Guiding violating vehicle	Guide team	Make the vehicle leave or U-turn after promoting sufficient awareness by using an alarm whistle and red flag, etc. based on the instruction made by the leader. When making the vehicle unloaded, guide the improperly loaded vehicle to the designated area.
11	Traffic regulation of temporary stopping	Warning team	Instruct a vehicle(s) entering the toll gate to stop temporarily by using an alarm whistle and red flag, etc., in case of making the vehicle U-turn.

[10]

2.6.15 Operation for Enforcement of Vehicles Carrying Hazardous Materials

In regard to a tunnel regulating hazardous materials (includes interchange and wayside amenities (rest areas) near the tunnel), enforcement staff shall interview drivers about contents and amount of the load, and take measures in accordance with Table 2-19 when a vehicle carrying hazardous materials is identified.

Table 2-19: Measures Taken for Vehicles Carrying Hazardous Materials

	Items	Taken by	Measures Taken
1	Instruction to the suspicious vehicle carrying hazardous materials	Warning team	Give the instruction to the driver to stop the vehicle temporally and move to a safe place (road shoulder etc.), where the vehicle shall not disrupt the traffic, for the confirmation of falling down prevention measures of the load or instruction of fixing / re-loading of the load, when an improperly loaded vehicle is found.
2	Move the vehicle to the designated area and report	Warning team	Move the suspected vehicles carrying hazardous materials, and report the contents of suspicious violation to the leader.
3	Traffic regulation of temporary stopping for the vehicle entry	Warning team	Make a vehicle(s), enter the toll gate, stop temporarily by using an alarm whistle and red flag, etc., based on the instruction made by the leader.
4	Guide the violating vehicle to the designated area	Guide team	Guide the vehicle to the designated area and make it stop temporarily by using an alarm whistle and red flag, etc., based on the instruction made by the leader.
5	Instruction of deregulation of traffic	Leader	Instruct the deregulation of traffic to the warning team when safety on the highway is ensured, after making the vehicle carrying hazardous materials move.
6	Re-open traffic for the temporarily stopped vehicles	Warning team	Reopen the traffic based on the instruction made by the leader.
7	Hearing, investigation, and Record	Measurement team	Inquire the contents and the amount of the load, conduct investigation. Then confirm and record the violation situations of the vehicle carrying hazardous materials.
8	Issuance of warning/instruction letter	Measurement team	Explain the content of the violation to the driver, and issue a warning/instruction letter.
9	Report of leaving highway/making U-turn etc.	Measurement team	Report the leader about the measure taken to the vehicle carrying hazardous materials to leave, U-turn or unload, etc.
10	Guiding violating vehicle	Guide team	Make the vehicle leave or U-turn after promoting sufficient awareness by using an alarm whistle and red flag, etc. based on the instruction made by the leader. When making the vehicle unloaded, guide the vehicle carrying hazardous materials to the designated area.
11	Traffic regulation of temporary stopping	Warning team	Instruct a vehicle(s) entering the toll gate to stop temporarily by using an alarm whistle and red flag, etc., in case of making the vehicle U-turn.

[10]

2.6.16 Handling Runaway Vehicle

In case a violating vehicle runs away during an enforcement operation, a leader shall collect and receive the following information which has been identified:

- Date and time of runaway
- Vehicle registration number, type, and freight
- Name of the driver
- Owner of the vehicle
- Situation of violation
- Runaway direction
- Other required information

If a violating vehicle is determined to significantly violate and may pose issues in safety as well as smooth traffic, a leader shall report such a situation to the Highway Operation team / the Traffic Control Center promptly.

2.6.17 Operation for Enforcement of Vehicles Refusing for Measurement etc.

In case a driver refuses to be measured his or her vehicle weight or size, to investigate the freight, to be presented relevant documents required to prepare a warning/instruction letter, a leader shall ask such a driver to cooperate with measurement, along with receiving the following information which has been identified from enforcement staffs.

- Date and time of enforcement
- Vehicle registration number, type, and freight
- Name of the driver
- Owner of the vehicle
- Situation of violation
- Other required information

2.6.18 Inspection and Report

Enforcement staff shall inspect and prepare the following items before leaving their office in order to perform enforcement activities.

- The operation condition of braking device and control device of operating vehicles for enforcement activities
- Visibility of rearview mirrors of operation vehicles
- Wear degree and air pressure of tires
- Amount of fuel of the vehicles
- Lightening condition of lights such as an alarm light of the vehicles
- Preparation of warning/instruction letter forms

CHAPTER 3 TUNNEL OPERATION

3.1 Purpose and Objective

The tunnel section shall require special attention for road disaster prevention because of the nature of closed space. Especially if an accident occurs inside tunnel although it rarely happens, it may be likely to expand serious accidents because vehicles are inflammable. Therefore, proper and efficient "Tunnel Operation" and "Tunnel Facilities" shall be required against road disasters including fire accidents. Emergency facilities for tunnels such as evacuation guide signs, fire extinguishers, push-button alarms, etc. shall be used by road users and relevant agencies such as police, fire defense agency, etc. for evacuation and/or fire-fighting purposes under an emergency situation, thus they shall be used easily as well as recognized clearly by road users. For this purpose, emergency facilities shall be standardized and adapted. This chapter states the required operation and facilities for arterial highways in mountainous regions.

3.2 Limitation

This chapter can apply to one / bi-directional tunnels with 2 traffic lanes in principle. However, it does not prevent applying this chapter to tunnels with equal to or more than three lanes with careful consideration for conditions of tunnels with large cross section.

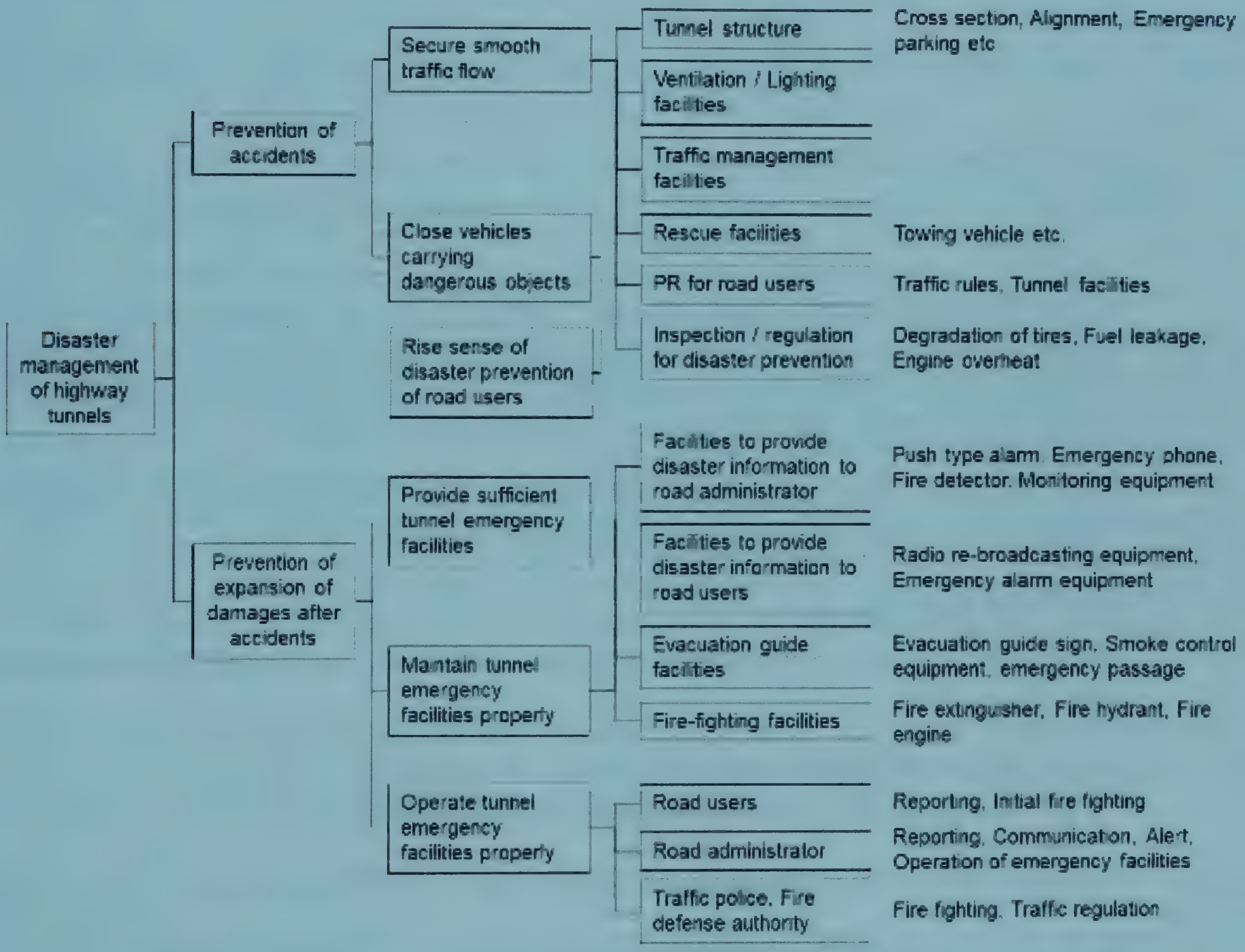
3.3 Framework

Major road disasters of the tunnel required special attention are 1) Fire accident, 2) Traffic accident and 3) Earthquake, especially it is required sensitive operation for disaster prevention of 1) Fire accident as stated in section 3.1.

Figure 3-1 shows the elements (components) to be considered for disaster management of highway tunnels. In principle, disaster prevention for highway tunnels can be divided into 2 phases, i.e. 1) prevention of accidents and 2) prevention of expansion of damages after accidents.

Prevention of accidents includes activities to make road users recognize potential disaster risks of tunnels, measures to make road users follow traffic rules and regulations, traffic management of tunnels as well as to provide proper tunnel structure (cross section, alignment) and tunnel facilities to prevent accidents inside tunnel such as tunnel ventilation system, lighting, emergency parking, etc. These are the most basic and important measures for disaster prevention of highway tunnels, and it is also important to operate these tunnel facilities properly. In addition, it is essential to recognize that traffic safety measures, such as proper alignment, road structure, traffic signs, etc. ahead of and after a tunnel section are important prevention measures for highway tunnels.

"2) the prevention of expansion of damages after accidents" is comprised of both physical measures and engineering measures. An approach of physical measures is to provide tunnel facilities with proper scale and appropriate arrangement. In contrast, an approach of engineering measures is how to operate these facilities properly (sufficient maintenance, proper operation, etc.). These physical and engineering measures are strongly related to each other, hence it is required to establish the prevention plan in consideration of the relationship between both measures.


Disaster management of highway tunnels
Prevention of accidents
Prevention of expansion of damages after accidents
Secure smooth traffic flow
Close vehicles carrying dangerous objects
Rise sense of disaster prevention of road users
Provide sufficient tunnel emergency facilities
Maintain tunnel emergency facilities properly
Operate tunnel emergency facilities properly
Tunnel structure
Ventilation / Lighting facilities
Traffic management facilities
Rescue facilities
PR for road users
Inspection / regulation for disaster prevention
Facilities to provide disaster information to road administrator
Facilities to provide disaster information to road users
Evacuation guide facilities
Fire-fighting facilities
Road users
Road administrator
Traffic police, Fire defense authority
Cross section, Alignment, Emergency parking etc
Towing vehicle etc.
Traffic rules, Tunnel facilities
Degradation of tires, Fuel leakage, Engine overheat
Push type alarm, Emergency phone, Fire detector, Monitoring equipment
Radio re-broadcasting equipment, Emergency alarm equipment
Evacuation guide sign, Smoke control equipment, emergency passage
Fire extinguisher, Fire hydrant, Fire engine
Reporting, Initial fire fighting
Reporting, Communication, Alert, Operation of emergency facilities
Fire fighting, Traffic regulation

[9]

Figure 3-1: Elements to be Considered for Disaster Prevention for Highway Tunnels

When we establish an overall disaster management plan for tunnels, it is critical that all these elements (components) including physical measures and engineering measures are functional comprehensively, and coherency is guaranteed as an overall plan. For example, tunnel facilities for the prevention of accidents are composed of elements for disaster management of highway tunnels; however, they are only a part of overall disaster management. Therefore, it is required to recognize that tunnel facilities are not sufficient for disaster management of highway tunnels, and it is required to develop an overall disaster management plan based on Figure 3-1.

In addition, a tunnel disaster cannot be managed by road administrators only, rather it highly requires cooperation with relevant agencies such as traffic police, fire defense agency, etc. as well as road users. As a matter of course, road users need to drive carefully in order not to happen traffic accidents. At the time of the disaster, they also need to take initial actions such as reporting to the road administrator, communicating with relevant agencies, conduct initial fire fighting for proper disaster management of highway tunnels. Traffic police and fire defense agency are the main players to extinguish a fire as well as regulate traffic in tunnels. Therefore it is required to include them in the disaster management plan, and also coordinate with them in order to make them take proper actions when an accident occurs in a tunnel.

3.4 Outline of Disaster Management of Highway Tunnels

Disaster management plan of highway tunnels gives priority shown in the following.

- ✓ Protection of the life of road users including the person who caused accidents
  - Initial fire-fighting, Early evacuation from a tunnel
- ✓ Prevention of expansion of damages after accidents
  - Full-scale fire-fighting, Traffic regulation inside and into tunnels

A tunnel is a closed space in nature, so road users may have difficulty evacuating from inside tunnels caused by heat, smoke, toxic gas, etc. if it takes a long time after a fire occurs. Tunnel facilities play a critical role to shorten the time for evacuation as well as minimize the scale of fire. It is necessary to make clear the purpose of each facility and operational method for maximum utilization of the facilities.

The following sections outline fire-fighting and evacuation/traffic regulations to be required for proper disaster management of highway tunnels.

3.4.1 Fire Fighting

Fire-fighting against a fire accident inside tunnel shall be divided into two stages, which are:

1) Initial fire-fighting by road users
2) Full-scale fire-fighting by a fire defense agency

Tunnel facilities shall be planned and provided in consideration of these two stages.

Generally speaking, a scale of a burning vehicle can become large easily in a short time. Therefore it is necessary to take initial actions immediately by the person who causes an accident as well as road users nearby. Initial actions below are required for disaster management of highway tunnels.

- ✓ Report: Unusual (Fire) situation is reported from the person who causes an accident etc. to the road administrator.
- ✓ Communication: The road administrator informs relevant authorities (traffic police, fire defense authority) and requests them to take necessary actions.
- ✓ Alert: The authority who receives the information (mainly road administrator) informs other road users about the unusual situation of a tunnel and makes them take proper actions in order to avoid secondary accidents.
- ✓ Initial fire-fighting: The person who causes an accident and/or nearby road users extinguish a fire.

- ✓ Evacuation: The person who causes an accident and/or road users inside a tunnel evacuate from an inside tunnel.

Based on past experience of fire accidents in tunnels, appropriate initial actions can minimize the expansion of damages after fire accidents, hence tunnel facilities for initial fire-fighting such as fire extinguishers, fire hydrants, etc. shall be recognized and operated easily by general road users. In this regard, the design, arrangement, operation methods of tunnel facilities for initial fire-fighting shall be standardized among all tunnels in India.

Full-scale (secondary) fire-fighting shall be entrusted to the relevant authority (mainly fire defense authority), however, it is required to design and arrange tunnel facilities for full-scale fire-fighting. From this point of view, the design, arrangement of tunnel facilities for full-scale fire-fighting shall also be standardized.

Moreover, some tunnel facilities need certain space for their installation, therefore it is required to design and arrange facilities in due consideration of methods for maintenance, inspection, rehabilitation, and replacement of these facilities.

3.4.2 Evacuation

Basically, road users need to evacuate from a tunnel under unusual situations by their own assessment of the situation in order to protect the life of road users and prevent the expansion of damages after accidents; however, evacuation circumstances vary widely by scale and kinds of fire and other accidents and timing of assessment, etc. From this point of view, a road administrator needs to assist the early evacuation of road users and keep a certain period of possible evacuating circumstances. In this regard, it is required to 1) collect and provide information from/to road users, 2) keep possible evacuating circumstances, 3) provide tunnel facilities to guide evacuation by road administrators.

For example, as a simple calculation, the period in Table 3-1 below is required for road users to evacuate from a tunnel. At least, a road administrator needs to secure this period of evacuating circumstances as a rough idea.

Table 3-1: Required Evacuation Period

Unit: Second

Vehicle speed (km/h)		20km/h	40km/h	60km/h	80km/h
Tunnel Length (m)	L=750m	135	67.5	45	33.8
	L=1,500m	270	135	90	67.5

Note: This table shows the time for running road users to recognize accidents and complete evacuation.

[9]

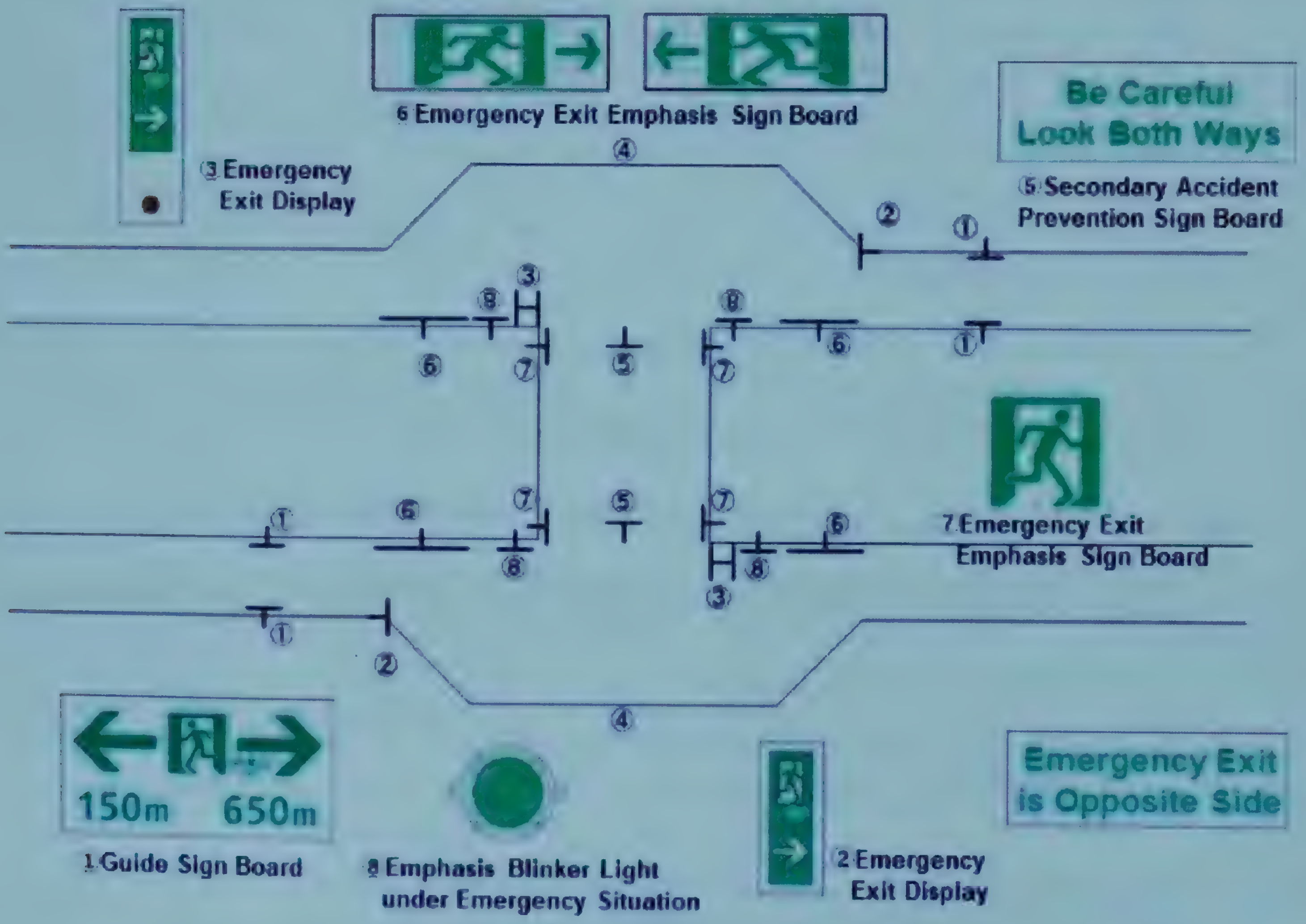
From this point of view, tunnel facilities for information collection and provision shall be used easily by road users to report accidents to a road administrator, and by the road administrator to provide information of accidents using collected information from road users and tunnel facilities and to guide evacuation road users from a tunnel immediately after accidents. It is also necessary to provide information provision facilities to regulate road users to enter a tunnel under unusual situations including fire accidents, accidents, and large earthquakes, etc. in order to avoid secondary accidents and damages.

Furthermore, it is important to highlight tunnel emergency facilities by a road administrator to be easily recognized by road users in order to make road users take appropriate actions including evacuation from a tunnel by themselves. Especially emergency exits of a tunnel are the most important facility so that road users can evacuate from a tunnel to other spaces; hence, the existence and location of these facilities shall be made clear even under the usual situation, and it is required to emphasize their existence and location when evacuation is needed under emergency situation.

Figure 3-2, Figure 3-3, and Figure 3-4 show the typical arrangement of an emergency exit and its facilities.

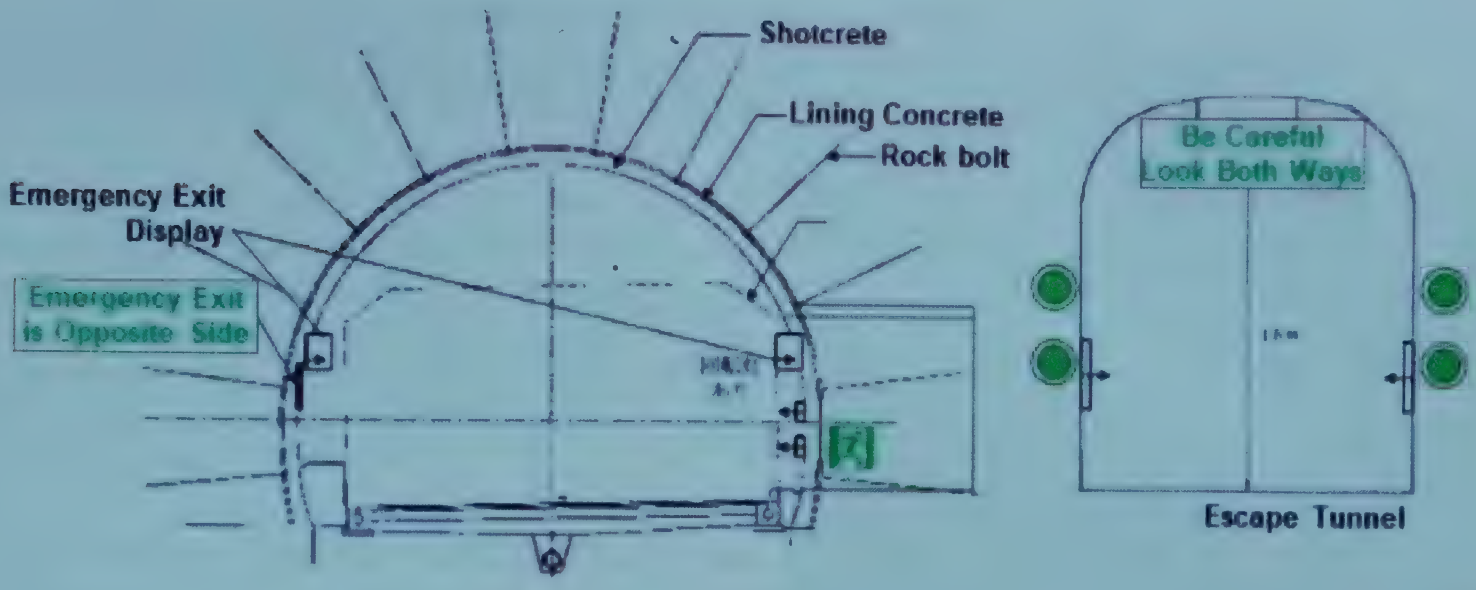
3.4.3 Continuous Tunnels Section

While a disaster management plan of highway tunnels shall be developed for each tunnel, it is not the case with continuous tunnels section, where intervals between tunnels are short (approx. 300m between the exit of a tunnel and entrance of another tunnel as a rough idea). For the development of a disaster management plan, a section of multiple tunnels situated in a short distance is required to be considered as a single tunnel-group over an entire continuous tunnels section. The disaster management plan includes a tunnel operation plan, arrangement plan of tunnel emergency facilities, and arrangement plan of information collection/provision facilities.


6 Emergency Exit Emphasis Sign Board
Be Careful
Look Both Ways
3 Emergency Exit Display
④
②
①
5 Secondary Accident Prevention Sign Board
③
⑧
⑥
⑦
⑤
7 Emergency Exit Emphasis Sign Board
150m
650m
1 Guide Sign Board
8 Emphasis Blinker Light under Emergency Situation
2 Emergency Exit Display
Emergency Exit is Opposite Side

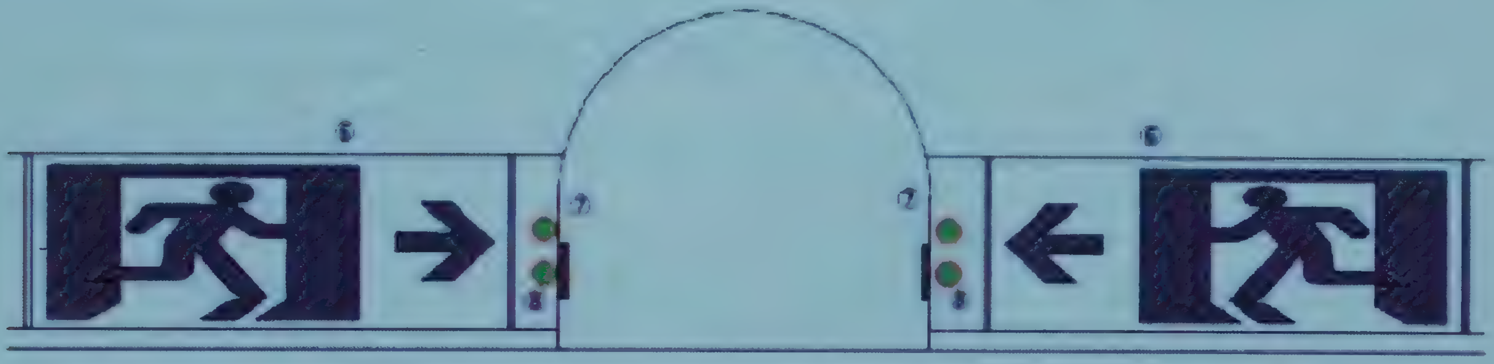
[9]

Figure 3-2: Example of Guide to Emergency Exit and Arrangement of Guide Boards



[9]

Figure 3-3: Example of Arrangement of Guide Boards around Emergency Exit



[9]

Figure 3-4: Example of Arrangement of Guide Boards around Emergency Exit

3.5 Tunnel Emergency Facilities

As mentioned in section 3.4, appropriate emergency facilities shall be provided to highway tunnels for proper tunnel operation in order to protect the life of road users and prevent the expansion of damages under the unusual situation, especially fire accidents inside a tunnel. This section shows an outline of tunnel emergency facilities required for highway tunnels.

When fire accidents and/or other accidents occur inside a tunnel, it is primarily crucial for a road administrator to avoid secondary accidents by providing accident information to other road users. For this purpose, the road administrator needs to collect accident information, grasp the situation of accident and inside a tunnel and alert road users as early as possible. A road administrator requires to prevent the spread and expansion of a fire, and minimize damages of fire. In addition, it is also important to guide the evacuation of road users inside a tunnel safely after fire accidents.

Table 3-2 summarizes items for tunnel emergency facilities.

Table 3-2: Required Tunnel Emergency Facilities

Large category	Middle category	Small category
Report and alert facilities	Emergency phone	
	Push-button alarm	
	Fire detector	
	Emergency information device	VMS at the tunnel portal VMS at tunnel inside
	Traffic Signal	
Fire-fighting facilities	Fire extinguisher	
	Fire hydrant	
	Hydrant	
	Water sprinkler	
Evacuation guide facilities	Guide signboard	Emergency exit display Guide signboard Emergency exit guide signboard
	Smoke discharge system or Evacuation route	Smoke discharge facility Escape tunnel Connection tunnel
Communication facilities	Radio communication	Leaky coaxial cable Emergency phone at the tunnel portal
	Radio re-broadcasting	
	Loudspeaker	
Monitoring facilities	CCTV cameras	Type A Type B
Other facilities	Lighting during power failure	
	Emergency power supply	Self-power generation system UPS

[9]

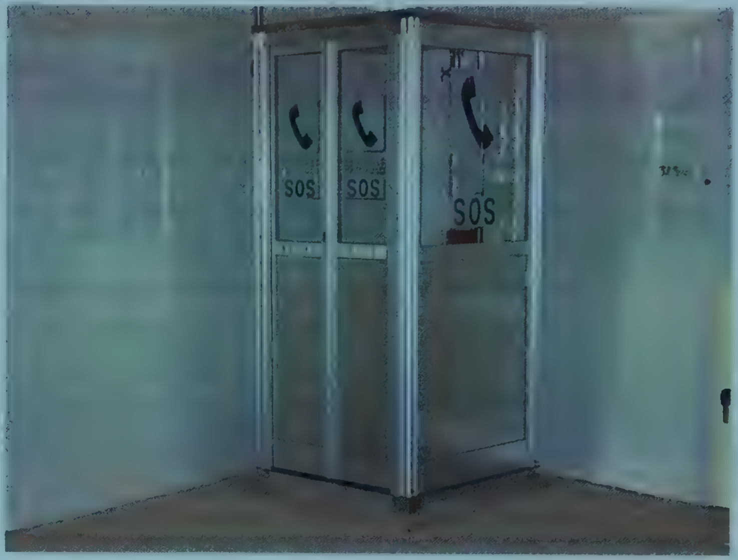
3.5.1 Report and Alert Facilities

Report and alert facilities aim to inform an occurrence of a fire and/or an accident to a road administrator or relevant agencies such as traffic police, fire defense agency, etc. as well as road users, etc. Report facilities include 1) Emergency phone, 2) Push-button alarm, 3) Fire detector. Alert Facilities provides information of a fire/accident which collected from report facilities to road users inside and nearby a tunnel and includes 4) Emergency information device and 5) Traffic Signal.

(1) Emergency Phone

An emergency phone is an exclusive phone to report an occurrence of a fire / an accident to a road administrator from a person who causes or finds an accident. An emergency phone is the most basic and important reporting facility because it can exchange large amounts of information between a tunnel inside and a road administrator.

The emergency phone shall provide inside callbox as shown in Figure 3-5 in order to block noise inside the tunnel (for this purpose, it is required to provide space inside the wall of a tunnel when a tunnel is constructed) and provide circumstances for smooth communications. It is also required to provide signboards with light to be recognized easily by road users.



[3]
Figure 3-5: Emergency Phone

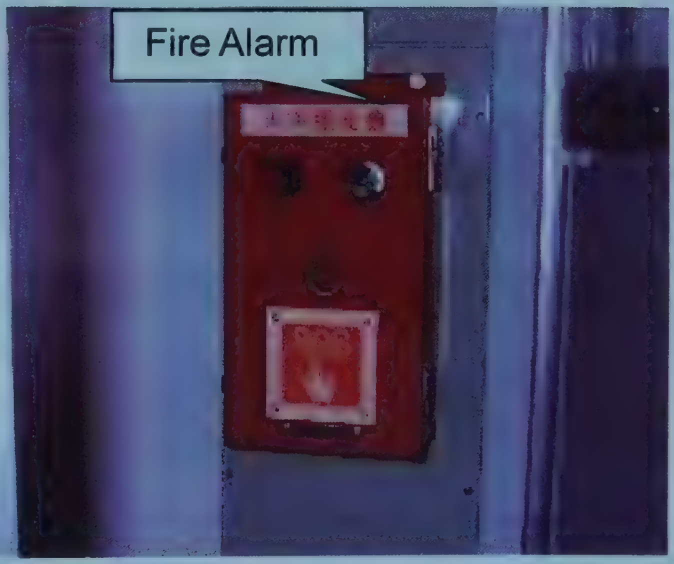
Moreover, the emergency phone is recommended to provide the following feathers for the easiness of usage:

- An emergency phone is automatically connected to the road administrator directly when a phone receiver is picked up
- The receiver is installed at 1.5m height etc.

(2) Push-Button Alarm

Push-button alarm aims to provide an alert to a road administrator by just pushing the button by a person who causes or finds an accident. The push-button alarm is an effective facility to report an accident to road administrators because it can operate easily by general road users.

The push-button alarm is required to put the plate mentioned "Fire Alarm" in order to avoid operation errors. Also, It is more convenient for road users, if the push-button alarm is installed together with the fire extinguisher and fire hydrant.



[3]
Figure 3-6: Push-button Alarm

(3) Fire Detector

A fire detector is a facility to detect a fire and inform a location of a fire to a road administrator automatically. A fire detector can report a fire accident immediately after it is detected, and it is effective to identify a location of a fire accident.

A fire detector shall provide a tunnel which is required to identify a location of a fire accident such as a long tunnel with heavy traffic volume, a tunnel with poor alignment, etc. because it is not a low-priced facility.

Usually, a fire detector recognizes a fire by detecting heat, smoke, and light of a fire, hence it is required to choose a fire detector with the function of high sensitivity to detect a fire and not affected by natural light and environment inside tunnels such as exhausted gas and thermal current by vehicles.

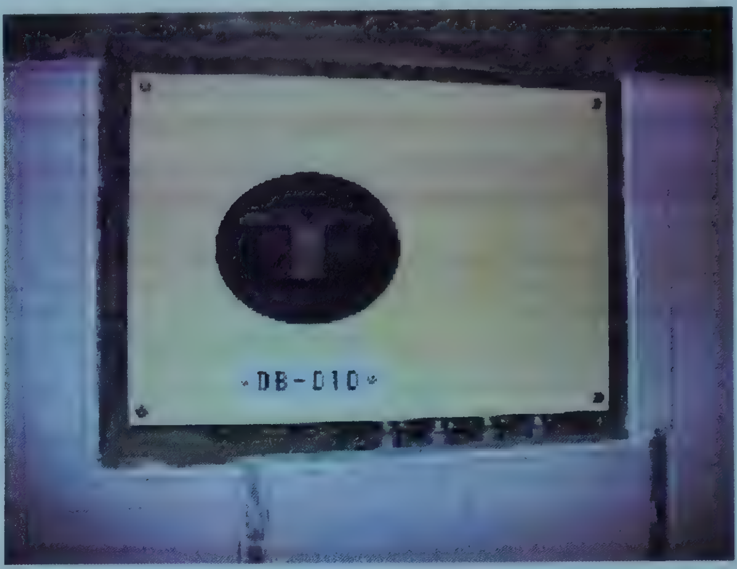


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Figure 3-7: Fire Detector

A fire detector shall be installed at a location where is not affected by natural light because it is technically difficult to distinguish natural light and light of fire by fire detector. For example, the section within 15m from the tunnel portal, is not required to install a fire detector. It is also not required to install a fire detector if the section is affected by natural light even it is inside a tunnel. Therefore, it is necessary to examine and survey the location where the fire detector is installed.

And it is more effective if water sprinkler and emergency information devices become stand-by mode in conjunction with a recognition of fire by fire detector, although it is required to confirm a fire by monitoring system (CCTV) finally and directly before initiating operation of these facilities.

In addition, it is required to provide a testing device to fire detector from a receiving board (remote area) because it is difficult to confirm whether it is operating normally or not at the site.

(4) Emergency Information Device

An emergency information device is a variable message sign (VMS) to provide information of a fire / an accident to road users inside / nearby a tunnel.

Emergency information device is categorized into two types, i.e. 1) VMS at tunnel portal which provides various information to road users before reaching and entering a tunnel and 2) VMS inside the tunnel which is installed at emergency parking in a tunnel and provide information to road users running inside a tunnel.

Emergency information devices shall have enough high visibility and high information provision capacity. It consists of three devices as shown below.

- ✓ Variable Message Sign (VMS): To show information of an accident in a tunnel
- ✓ Blinker light: To alert road users to the unusual situation in a tunnel as well as to draw attention from road users to VMS by flashing and/or blinking a yellow/red color light.
- ✓ Warning sound device: To draw attention from road users by generating warning sound against an unusual situation in a tunnel. It can be installed only to 1) VMS at tunnel portal, because it may disturb evacuation of road users, if it is equipped with 2) VMS inside tunnel.

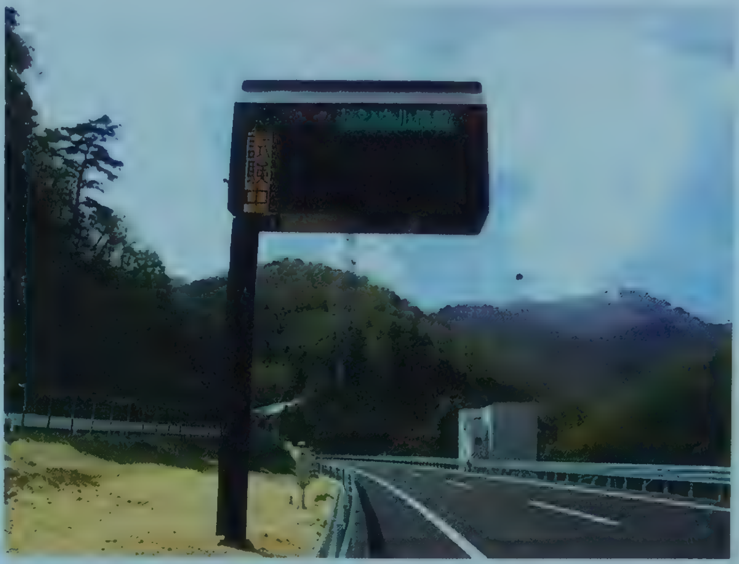

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Figure 3-8: VMS at Tunnel Portal

VMS at the tunnel portal provides road users with information about an accident inside the tunnel before they enter into a tunnel. It aims to minimize the scale of an accident by regulating traffic to enter a tunnel and by preventing road users from being involved in a secondary accident. Since VMS at tunnel portal is an important facility, it is required to be installed at all tunnels except for a short length tunnel which can see an exit of a tunnel from its entrance.

VMS at tunnel portal shall be installed at certain distance from a tunnel portal (approx. 300m as a rough idea) because it is required to stop road users with certain distance (approx. 50m) from a tunnel portal after they recognize the unusual situation of a tunnel by VMS in order not to disturb fire-fighting activity by fire defense agency and evacuation of road users in a tunnel. It is also required to provide supplemental VMS at a tunnel portal in case VMS and tunnel portal are not visible at the same time, and it is difficult to keep a 300m distance from an exit of a tunnel to an entrance of the next tunnel.

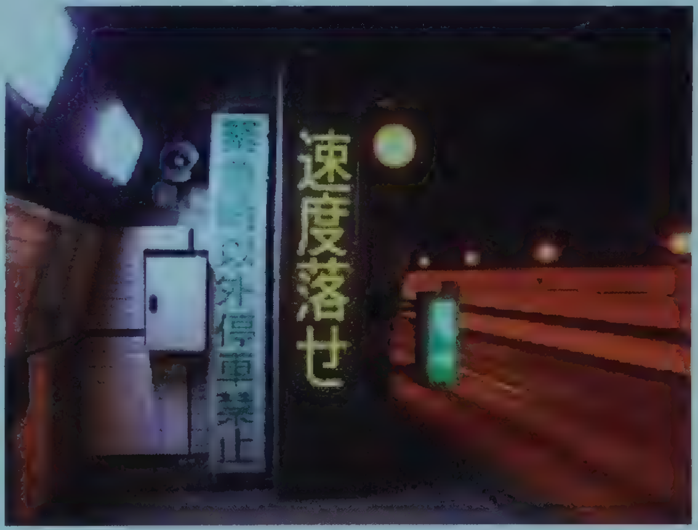

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Figure 3-9: VMS inside tunnel

VMS inside the tunnel shall be installed at emergency parking in a tunnel and the location where road users can recognize it easily.

Since VMS inside tunnel provides different information between road users moving towards to and road users running away from a location of an accident. VMS inside the tunnel shall be installed only in the tunnels which have facilities to collect information of the occurrence and a location of an accident certainly and emergency parking which provide space to install VMS inside the tunnel.

(5) Traffic Signal

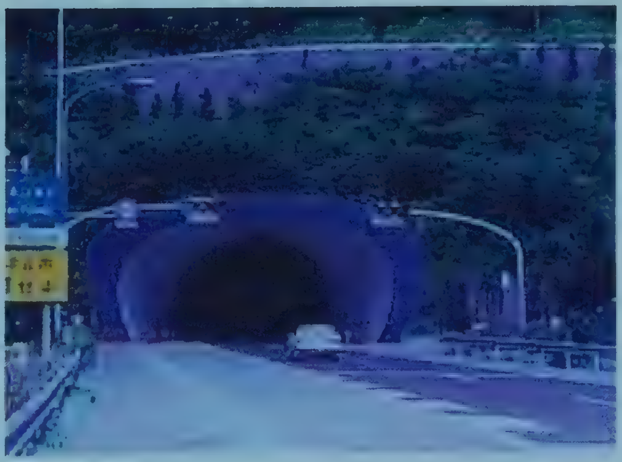

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Figure 3-10: Traffic Signal

A traffic signal is an effective facility to regulate traffic entering a tunnel. The red right of a traffic signal can be easily recognized by road users, who will stop their vehicles surely.

Since many traffic signals cannot be installed on access-controlled highways or semi-access-controlled highways, it shall be installed to a tunnel which needs to regulate traffic entering a tunnel surely such as a tunnel with heavy traffic, etc.

Traffic signal shall be installed at a certain distance from a tunnel portal (approx. 50m) because it is required not to disturb fire-fighting activity by fire defense agency and evacuation of road users from a tunnel.

3.5.2 Fire-Fighting Facilities

Fire-fighting facilities include 1) Fire Extinguisher, 2) Fire Hydrant, 3) Hydrant and 4) Water Sprinkler". Basically fire-fighting works can be divided into two stages of "Initial fire-fighting" and "Secondary (full-scale) fire-fighting". "Initial fire-fighting" is targeted to be conducted by road users who caused and/or found a fire accident. On the other hand, "Secondary (Full-scale) fire-fighting" is implemented by a fire defense agency and road administrator. Hence fire-fighting facilities are also categorized into two types to conduct initial fire-fighting (Fire Extinguisher and Fire Hydrant) and to assist secondary fire-fighting (Hydrant and Water Sprinkler).

As stated in Section 3.4, in order to extinguish a fire or minimize the expansion of damages at a time of a fire accident, it is required for road users at the scene of a fire accident in a tunnel to conduct fire-fighting works smoothly and effectively, hence it is important to provide such fire-fighting facilities.

(1) Fire Extinguisher

A fire extinguisher is provided in a tunnel for initial fire-fighting work. A fire extinguisher is an essential facility and less expensive. It shall be equipped with all tunnels because general road users are familiar with a fire extinguisher and easily recognize it as a fire extinguisher. A fire extinguisher can be used for small-scale fire accidents. In this regard, fire extinguishers shall be used and handled easily even by general road users.

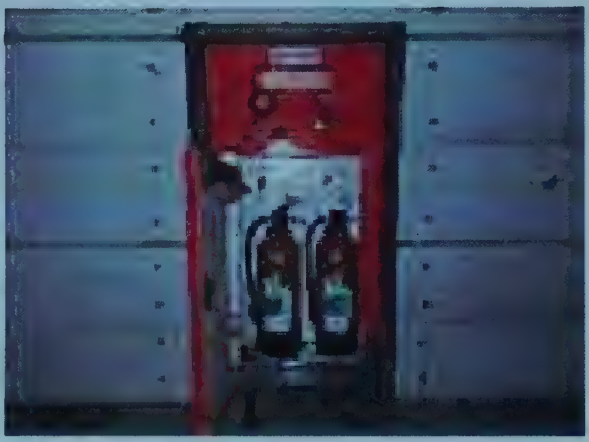

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Figure 3-11: Fire Extinguisher

Several types of fire extinguishers are available on the market along with variety and complex of fire accidents, thus fire extinguishers shall be selected in consideration of its performance for fire extinguishing, condition of application etc. Generally fire extinguisher is categorized into some types, depending on the kind of object for fire extinguishing as shown in below.

- ✓ Type A: Normal fire accident for wood, paper, textile, etc.
- ✓ Type B: Oil fire accident for petrol, kerosene, etc.
- ✓ Type C: Electric fire accident for electric equipment/facility when applying current etc.

It is required to consider the following conditions when fire extinguisher for highway tunnels is selected.

- ✓ Generally, the type and scale of a fire accident in a tunnel depend on the variety and amount of loading on a vehicle; therefore, a fire extinguisher needs to have the ability to extinguish all types of a fire accident, i.e. Type A, B, and C. It is also required to have a high capacity of fire extinguishing for Type B fire accidents in consideration of the specialty of a fire accident of a vehicle in a tunnel.

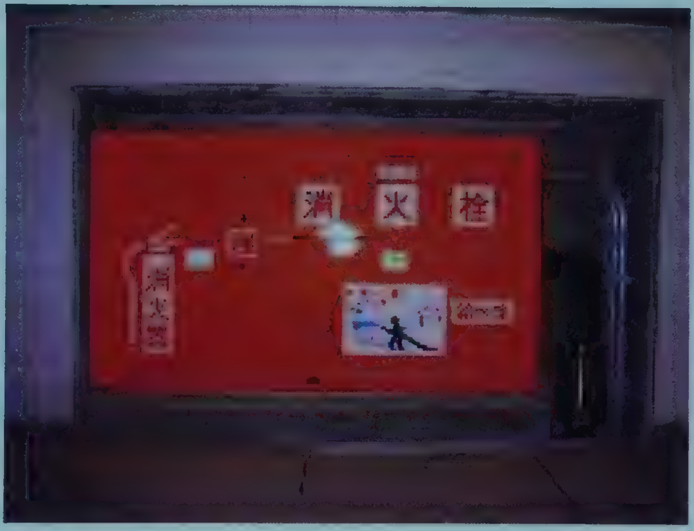
- ✓ The fire extinguisher shall be placed, carried, and operated against a fire accident even in a narrow space like a tunnel.
- ✓ The fire extinguisher shall not generate toxic gases when it is used.
- ✓ The fire extinguisher shall have high durability and is hard to transform against temperature, humidity, etc.
- ✓ The fire extinguisher shall be maintained easily.

The fire extinguisher shall be placed inside a box in pairs so that fire-fighting can be conducted concurrently by two persons. It is also required to place a board clearly mentioned "Fire Extinguisher" on a box. Moreover, it is more efficient and effective for fire-fighting if a fire extinguisher is placed together with a fire hydrant.

(2) Fire Hydrant

A fire hydrant is a watering facility for normal size fire accidents. A fire hydrant shall be used by road users for initial fire-fighting. Compared to a fire extinguisher, a fire hydrant has a higher capacity for fire extinguishing; however, it is a little more complicated to use.

It is required to ensure certain pressure is given to the water hydrant in order to get the required water pressure and amount for fire-fighting operation. It can be realized by installing a water tank at a higher position than the water hydrant, or starting the pump by remote control by pushing the start switch at the water hydrant location. It shall be decided how to secure this certain pressure in consideration of the site condition of a tunnel.



Note: Fire extinguisher is installed in the left box, and Fire hydrant is installed in the right box

[3]

Figure 3-12: Fire Hydrant

Watering amount and pressure of fire hydrant shall be decided to consider the capacity of fire extinguishing as well as the easiness of operation because it shall be used also by ladies, elder persons, etc. (Preferably 130 liter per minutes, 0.29 MPa (3.0 kgf per m2) as a rough idea).

Furthermore, it is required to install a fire hydrant at certain intervals as well as to decide the length of hose of the fire hydrant in order to conduct fire-fighting works for a fire accident using multiple fire hydrants at the same time.

(3) Hydrant

Hydrant shall be installed to assist secondary (full-scale) fire-fighting works by the fire defense agency and/or road administrator.

A hydrant is installed in a tunnel which water hydrant is installed as an initial fire-fighting facility. And it is also required to install water supply inlet(s) at both tunnel portals to supply water to the hydrant in a tunnel from fire truck(s) etc. In addition, it is necessary to place the board or sign mentioned "hydrant for fire defense agency" in order to be recognized by the agency as well as to avoid misunderstanding by road users.

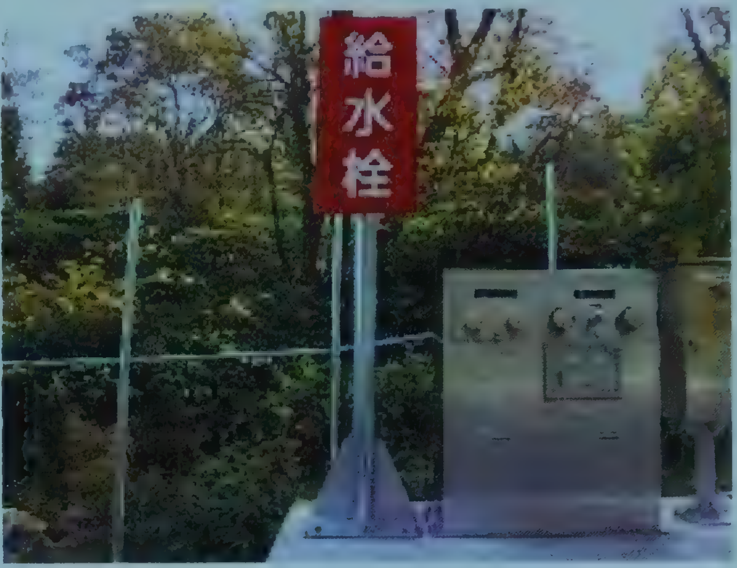


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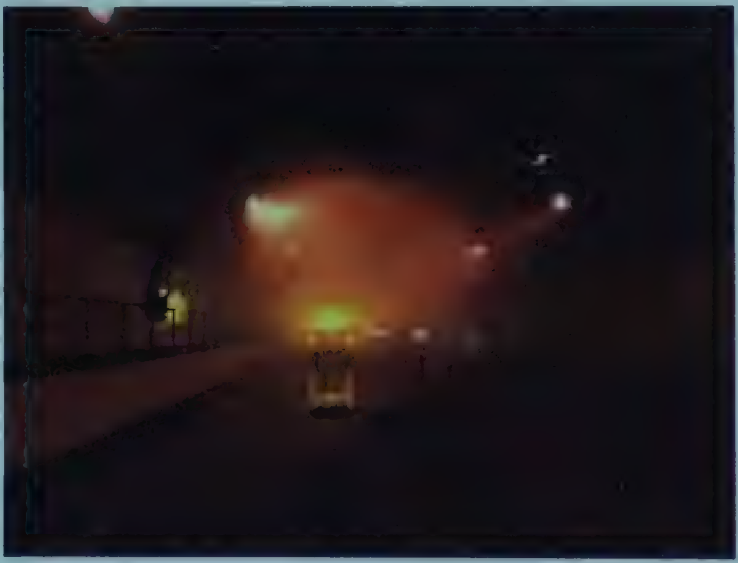
Figure 3-13: Hydrant

Because hydrant is usually used by fire defense agency, details of hydrant such as on/off valve of the hydrant, type of a connection between hydrant and watering hose, etc. shall be decided in close discussion and cooperation with fire defense agency. The location, interval, heights (0.5 to 1.0m as a rough idea for using easily by fire defense agency) of the hydrant to be installed, water pressure, the amount for watering shall be also decided together with the fire defense agency.

(4) Water Sprinkler

Water sprinklers can assist fire-fighting works to cool a source and reduce the energy of a fire accident by spouting out pressured mist water from nozzles installed on sidewall of a tunnel by remote control. There are four major effects and roles of water sprinklers as follows:

- ✓ Reduce energy of a fire accident
- ✓ Minimize expansion of a fire accident at a fire source
- ✓ Protect tunnel structure from a fire accident
- ✓ Protect tunnel facilities from a fire accident



[3]

Figure 3-14: Water Sprinkler

Water sprinkler has an advantage which can be operated by remote control from tunnel management center etc.; however, a road administrator should pay attention to the fact that water sprinkler may disturb evacuation of road users, since water sprinkler may let mist water and smoke of a fire accident fall down to the ground level in a tunnel, which phenomenon is proved by past experience and experiments of a fire in a tunnel. Therefore, it shall be required to monitor and confirm the situation in a tunnel by the operator in a tunnel management center, etc. when the operation of the water sprinkler has been started.

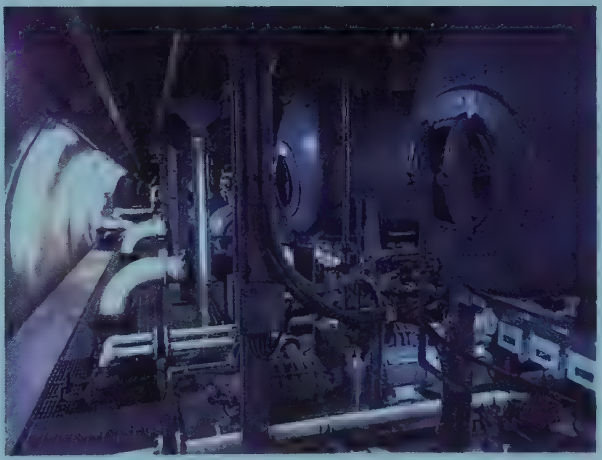
Water sprinkler consists of automatic water supplying valve devices, nozzles of water spouting, water supply pipes, pumps for pressurization, water tanks and control device. It is required for a control system of water sprinkler such as material and route of cables etc. to be selected in consideration of fire resistance in order to avoid damages by a fire accident.

Water sprinkler needs to keep certain pressure and amount for spouting water during watering in consideration of a scale of a fire accident (Pressure: 0.34 MPa, Amount: 6 liters per minutes*square meter, as a rough idea). Type, interval, the direction of nozzles of water sprinkler shall be designed and arranged to spout water with uniformity inside traffic clearance as much as possible. In addition, water sprinkler shall be controlled with the section of over 50m-length, and be decided in consideration of water spouting performance of water sprinkler and intervals of other tunnel emergency facilities such as fire detector, CCTV cameras, etc. It is also required to control spouting water from continuous two sections at the same time to spout water to a fire accident that occurred at the boundary of sections.

Since the water detector is not a low-priced facility, it shall install a tunnel which requires high conscious disaster management such as a long tunnel with heavy traffic volume, a tunnel with poor alignment, etc.

(5) Water Supply System

Apart from tunnel emergency facilities inside a tunnel, a water supply system shall be installed to supply water to water hydrant, hydrant, and water sprinkler. The water supply system consists of the main water tank(s), priming tank, water pipes, and water pumps. Water for tunnel fire-fighting works shall be kept from public/private water supply in principle~~,~~ because public/private water supply can provide a certain amount of water stably even in the dry season; however, if it may be difficult to keep water from public / private water supply, depending on the location of a tunnel etc.~~,~~ In such a case, water shall be acquired from tunnel spring water, groundwater, and/or river, stream, pond nearby a tunnel. In this case, in order to get a certain amount of water (preferably main tanks can be filled within 12 hours) from spring water, groundwater, river, etc., it is required to survey the amount of water during the dry season.



[3]

Figure 3-15: Water Supply System

The capacity of main tanks shall be decided depending on installed facilities to a tunnel. Main tanks need to store the amount of water which watering can be conducted continuously in 40 to 60 minutes through three water hydrants, two hydrant and two sections of water sprinkler at the same time with approx. 20% extra. Besides if cooling water for the ventilation system etc. is required, it shall be added to the capacity of main tanks. Main tanks shall be made of RCC in principle in order to avoid water leakage by earthquake, wind, corrosion, and deterioration of the material, and inspection window, rudder, depth meter are provided to main tanks for inspection, if necessary. The water inside the water tank shall be supplied automatically from a source of water when the water level is lowered.

Priming water tank is required 1) to fill water up inside water supply pipes constantly to conduct fire-fighting works quickly and smoothly when a fire accident occurs, 2) to keep certain pressure to start operation of automatic valve as well as 3) for priming water for pumps. The capacity of the priming water tank shall be preferably 1 m^3 (cubic meter) as well if it is installed independently. It is also required to prevent freezing of water in a priming water tank in the winter season if a tunnel is located in the cold area.

3.5.3 Evacuation Guide Facilities

Evacuation guide facilities can direct and assist the safe evacuation of road users ~~to~~ outside a tunnel who meet and are involved in a fire accident and/or other accidents. Evacuation guide facilities are divided into three types, as follows:

1) Guide signboard which can assist the evacuation of road users indirectly by providing information
2) Smoke discharge system
3) Escape tunnel which can assist evacuation directly.

(1) Guide Sign Boards

Guide signboards shall be installed to guide road users to outside a tunnel when fire and/or other accident is occurred by providing information for the distance, direction, and location of tunnel exits or emergency routes. Three types of guide signboards are required to install to a tunnel, which are;

- ✓ Emergency Exit Display: Show and highlight the location of an emergency exit
- ✓ Guide Sign Board: Show the location, direction, and distance to a tunnel exit and/or an emergency exit
- ✓ Emergency Exit Guide Sign Board: Show the location of emergency exits (Supplemental sign of "emergency exit display")

In principle, these displays and signboards shall be "Inside lighting type" in case these are installed to a tunnel with emergency exits, i.e. with an escape tunnel route, because inside lighting type of signboards can be recognized more clearly by road users and can show the location of emergency exits more surely compared to reflection type of signboard, even these are located in a dark tunnel and evacuation routes are complicated. These displays and signboards are usually installed above a pedestrian path inside a tunnel; therefore, it is required to install over 1.8m from road level to avoid disturbing evacuation of road users under emergency situations.

On the other hand, in case a tunnel without emergency exits, reflection type can be used for these displays and signboards, because a tunnel length is comparatively short and the evacuation route is simple (only tunnel portals). Aluminum type boards shall be used for these reflection types of displays and signboards in consideration of non-combustibility and corrosion resistance. It is also required to put a framed box around these displays and signboards because road users can recognize them more easily. However even a tunnel does not have emergency exits, these displays and signboards shall be "Inside lighting type" if a tunnel requires more strict disaster management such as a long tunnel with heavy traffic, a tunnel with poor alignment, etc.

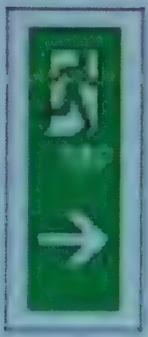


Figure 3-16: Emergency Exit Display

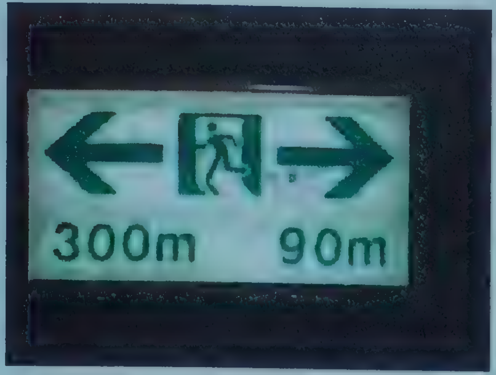
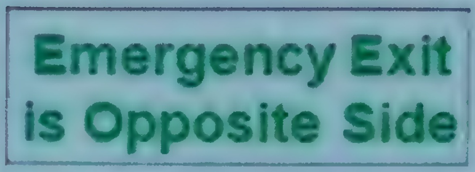


Figure 3-17: Guide Sign Board



[3]

Figure 3-18: Emergency Exit Guide Sign Board

(2) Smoke Discharge System

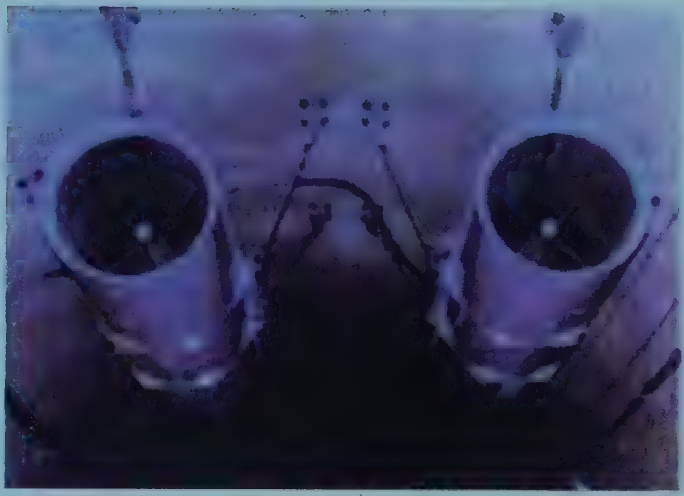


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Figure 3-19: Smoke Discharge System

A smoke discharge system shall be installed to minimize diffusion of smoke in a tunnel by a fire accident in order to keep proper evacuation circumstances as well as it can be used for discharging smoke-filled in a tunnel to tunnel outside forcibly after a fire under control to assist fire-fighting works.

Usually, ventilation system such as jet-fan, etc. can be used as a smoke discharge system; however, it shall be required to install a smoke discharge system independently even a tunnel does not require a ventilation system in case a tunnel length exceeds 1,500m, because a tunnel with 1,500m length has emergency exits (escape tunnel) based on the Guideline of Road Tunnels (IRC: SP:91) and evacuation routes are complicated compared to a tunnel with less than 1,500m lengths.

Past experience and experimental facts show that fire smoke can be controlled, i.e. smoke can be flowed to the expected direction by over 2 m/s wind velocity; however, a fire is fanned by approx. 4 to 5 m/s wind velocity. Because a smoke discharge system is installed for the purpose of keeping proper evacuation circumstances when a fire occurs in a tunnel, it is required to control wind velocity from 2 m/s to 4 to 5 m/s to discharge smoke as well as to prevent the expansion of a fire inside a tunnel. Nevertheless, it is difficult to uniformly decide the operational method of smoke discharge system for all tunnels, because the type of smoke discharge system, location and scale of a fire accident, velocity of natural wind in a tunnel, and traffic volume and direction are different for each of tunnels. Therefore, it is required to prepare the "Tunnel Operation Manual" which directs the operational method of the smoke discharge system in each tunnel. The chapter of tunnel facilities in "Guidelines for Tunnels" stipulates the design of a smoke discharge system.

(3) Evacuation Route

The evacuation route consists of an escape tunnel (i.e. egress tunnel) and a connecting tunnel. It shall be provided to let road users evacuate to tunnel outside easily when an accident occurs in a tunnel. An escape tunnel is a tunnel which is provided independently and parallel to the main tunnel to assist evacuation and rescue activities. It is called an egress tunnel. A connection tunnel, on the other hand, is a tunnel to connect between the main tunnel and escape tunnel or 2nd main tunnel (opposite direction). The entrance of the emergency route is called an emergency exit.

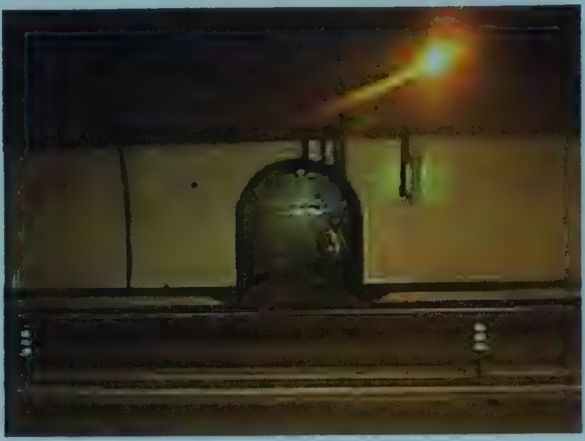

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Figure 3-20: Evacuation Route

Escape tunnel has an advantage certainty of evacuation; however, generally, it is much costly compared to other facilities to assist evacuation activities such as smoke discharge system, etc. Therefore, it is required to provide an escape tunnel to a tunnel which requires high-level disaster management. In this regard, the Guideline of Road Tunnels (IRC: SP:91) specifies that a tunnel with 1,500m length shall be equipped with an escape tunnel.

A standard interval of escape tunnel is shown in Table 3-3. Basically escape tunnel is arranged together with an emergency parking bay to enhance evacuation. Since the larger section of excavation is necessary for the location of an emergency parking bay, such location is more likely to be susceptible to the geological condition. In the case of a bi-directional single tunnel, the standard interval of escape tunnel is about 350m. The interval can be compromised to 300-400m in a place where the geological condition is poor. In the case of a uni-directional twin tunnel, the standard interval of the escape tunnel is about 750m. The interval can be compromised to 700-800m in a place where the geological condition is poor.

Table 3-3: Interval of Escape Tunnel

Type of Tunnel	Interval of Escape Tunnel	
	Standard interval	Where the geological condition is poor
Bi-directional Single Tunnel	About 350m	300m ~ 400m
Uni-directional Twin Tunnel	About 750m	700m ~ 800m

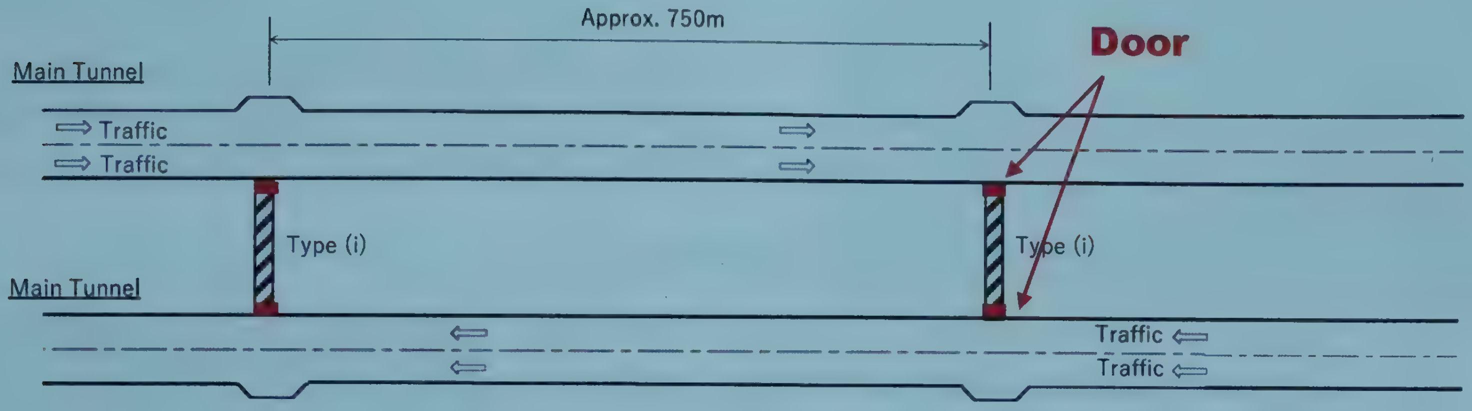
[3]

On evacuation connection tunnel, emergency exit doors should be installed, as in Figure 3-21.

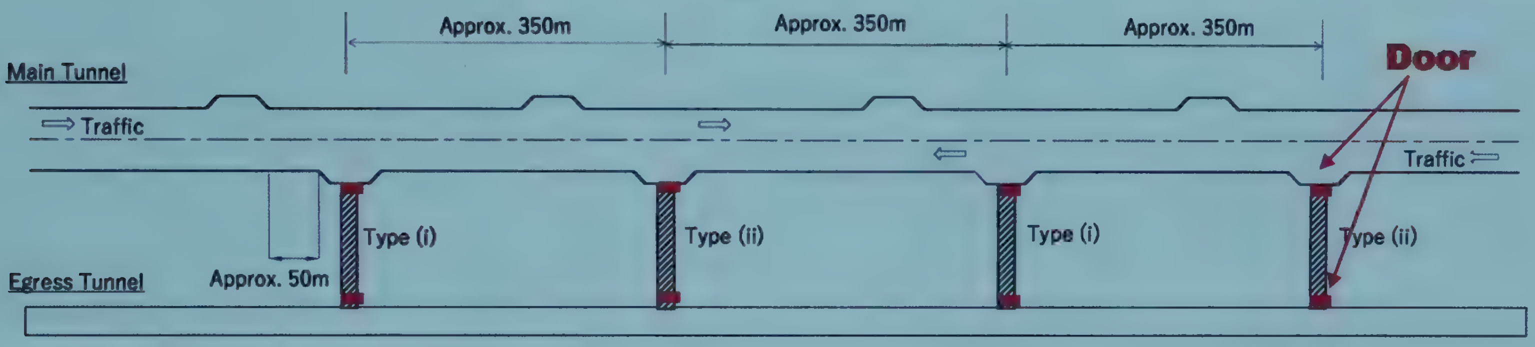
The door aims to prevent smog and fire intruding into the emergency connection tunnel and egress tunnel / another tunnel tube. The doors aim to guarantees safe evacuation of road users, by preventing smog and fire from entering into another tunnel.

Doors at the evacuation connection tunnel should have good fireproof performance as well as good durability under the tunnel environment in terms of wind, humidity, exhaust gas from vehicles, and dust. It should also have good airtightness to prevent smog on the other side of the door. Moreover, the door should be easily opened by hand; the required force should be less than around 49N ~ 59N. As in Edited from

Figure 3-21, two doors are commonly installed in the evacuation connection tunnel. The sign that says “Emergency exit” should be displayed on the door.


Approx. 750m
Door
Main Tunnel
Traffic
Traffic
Type (i)
Type (i)
Main Tunnel
Traffic
Traffic

(a) Uni-directional Twin Tunnels


Approx. 350m
Approx. 350m
Approx. 350m
Door
Main Tunnel
Traffic
Traffic
Type (i)
Type (ii)
Type (i)
Type (ii)
Egress Tunnel
Approx. 50m

(b) Bi-directional Single Tunnel

Edited from [3]

Figure 3-21: Arrangement of Emergency Exit Door

Commonly, there are two types of doors; type(i) for both pedestrians and emergency vehicles, and type (ii) for only pedestrians. For type (i) door, two sizes of doors, one for pedestrian and the other for an emergency vehicle, are accommodated at one door. As for the pedestrian door, it should be kept open at a certain time (around 60 seconds) and then should automatically be closed regardless of any position of the door opened. It is to be noted that doors should not use complex mechanisms nor an external power supply.

3.5.4 Communication System

A communication system shall be provided to supplement “Report and alert facilities” and “Evacuation guide facilities” and to make evacuation, rescue, and fire-fighting activities more efficient and effective. A communication system includes the following three items:

1) “Wireless communication auxiliary system (“Leaky coaxial cable” and “Emergency phone at tunnel portal”),
2) “Radio re-broadcasting system”
3) “Loudspeaker”

(1) Wireless Communication Auxiliary System

The main user of the wireless communication auxiliary system is the fire defense agency. It aims to secure communication between inside and outside a tunnel during the course of fire-fighting works. It generally consists of "Leaky Coaxial Cable" and its incidental equipment. Since the heat resistance of leaky coaxial cable from heat and fire is limited, a tunnel which requires high-level disaster management shall be equipped with a dedicated emergency phone also at both tunnel portals to communicate with inside a tunnel as compensation for the limited heat capacity of leaky coaxial cable. The location of leaky coaxial cable inside the tunnel shall be outside of clearance of lanes so that the cable shall not be fallen down on the lanes even if it fails.

(2) Radio Re-broadcasting System

Generally inside tunnels becomes a black spot for radio broadcasting, because waves of radio broadcasting cannot reach the inside tunnel if its length is comparatively long. Therefore it is required to install antennas to receive and amplify radio broadcasting waves, and an inductive line to broadcast a radio program to road users in a tunnel. Because this radio re-broadcasting system can send information to road users in a tunnel, it can be used to send information of an accident and/or evacuation in a tunnel by a road administrator by interrupting the usual radio program when an accident occurs in a tunnel. It can be used for information provision and evacuation direction to the road users in in a tunnel, preferably it is installed to a tunnel which is installed together with the monitoring system or emergency exits (escape tunnel).

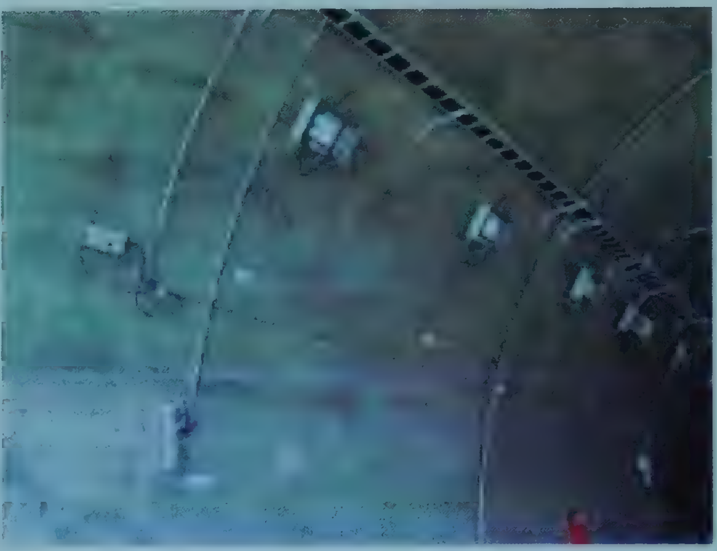

[3]

Figure 3-22: Radio Re-broadcasting System

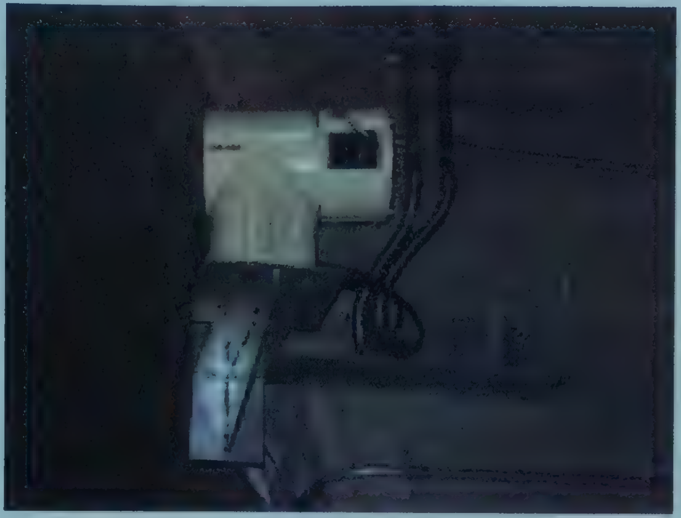
(3) Loudspeaker

Loudspeaker aims to provide information to road users who get off their cars to evacuate from a tunnel. The sound of a loudspeaker is difficult to reach passengers inside a vehicle, therefore the loudspeaker is targeted to provide information to road users who take off their cars following information and guide from radio re-broadcasting system, etc. In this regard, a loudspeaker shall be installed in a tunnel where a radio re-broadcasting system is installed.

3.5.5 Monitoring System

Although a monitoring system requires high facility costs, it shall be provided in a tunnel as much as possible. This is because a road administrator and relevant agencies such as police, fire defense agency, etc. can monitor traffic flow in a tunnel from such as tunnel operation center, etc. under usual situations as well as an accident, fire-fighting works, evacuation under emergency situations.

A monitoring system can be categorized into two types of Type A and Type B.



[3]

Figure 3-23: Monitoring System

- ✓ Type A: CCTV cameras shall be arranged in certain intervals (e.g. 200m depending on the capability of cameras) to monitor a whole areas inside a tunnel. These CCTV cameras can be used to identify the occurrence, scale, and location of an accident in a tunnel and also to confirm the situation in a tunnel when evacuation guide and/or operation of smoke discharge system and water sprinkler are going to start. Especially, it shall be confirmed that no persons are in the area when the water sprinkler system is going to be operated, hence it is required to secure proper surveillance area by each camera as well as a line of cameras. These cameras can be used to confirm traffic flow in a tunnel under the usual situation.
- ✓ Type B: CCTV cameras with a zoom-up function shall be arranged at every emergency parking bays in a tunnel to confirm the scale and location of an accident in a tunnel as well as the situation around emergency exits in order to guide evacuation of road users.

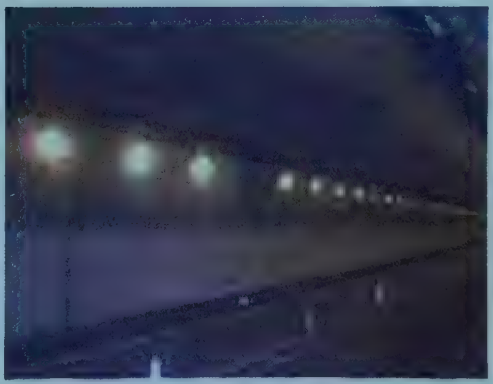
3.5.6 Other Facilities

"Lighting system during Power Failure" and "Emergency Power Supply system" are categorized into other facilities.

(1) Lighting System during Power Failure

A lighting system during power failure shall be installed in a tunnel to secure minimum lighting in a tunnel in order to avoid secondary accidents when power failure and/or a fire accident occur. There are two types of supply methods of electricity. One is through Uninterruptible Power Supply (UPS) system, and the other is through a self-power generation system.

Lighting systems during a power failure can contribute to improving safety in a tunnel as well as can assist fire-fighting works and evacuation of road users. Thus, in principle, it shall be installed in all tunnels except for short tunnels (tunnel length is less than 200m as a rough idea).



[3]

Figure 3-24: Lighting System during Power Failure

(2) Emergency Power Supply System

An emergency power supply system shall be installed in a tunnel to secure the function of tunnel emergency facilities except for the smoke discharge system even if the power failure occurs. There are two types of emergency power supply systems. One is the "Uninterruptible Power Supply (UPS) system" which can secure the function of the lighting system during power failure and major tunnel emergency facilities for a certain period (usually approx. 10 minutes) after a power failure occurs. The other emergency power supply system is the "Self-Power Generation System" which can secure the function of tunnel emergency facilities for a long period.

An emergency power supply system shall be installed in a tunnel with over 500m length. This is because in case tunnel length is less than 500m lengths, opposite side of tunnel portal (i.e. evacuation route) is generally visible from road users who is about to enter into a tunnel and also psychological fears for an accident and/or fire is limited compared to a long tunnel. However, the system shall be installed if a tunnel requires more strict disaster management such as a long tunnel with heavy traffic, a tunnel with poor alignment, etc.

UPS system is mainly used for lighting system during a power failure, hence it is not required to install UPS system to a tunnel which lighting system during power failure is not provided.

3.6 Tunnel Operation and Arrangement of Tunnel Emergency Facilities

3.6.1 Tunnel Operation

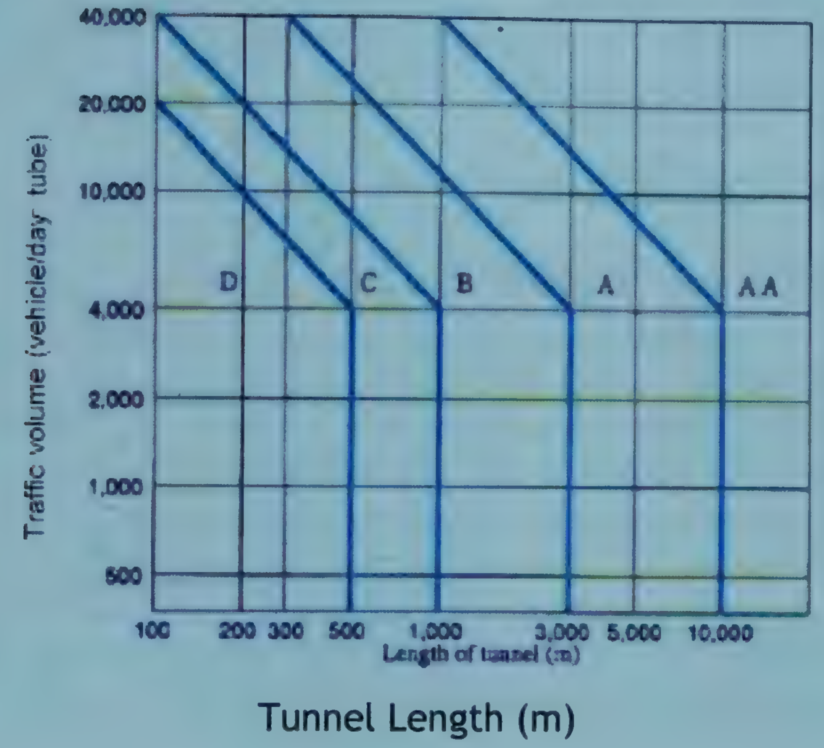
As described in Chapter. 8 of the Guidelines for Road Tunnels (IRC:SP:91), the appropriate operation shall be planned and conducted to maintain a specified level of safety for road users, to ensure free flow of traffic in tunnels, to optimize the level of expenditure, and to deal with abnormal situations such as traffic accident, fire accident, etc. in tunnels. In order to achieve efficient and effective tunnel operation, it is required to prepare operation manuals for various activities, which are described in Section 8.4 "Documentation" of the Guidelines for Road Tunnels (IRC:SP:91), plants and equipment, overall maintenance schedule in detail, which should be made available for operating staffs.

Especially, it is essential to plan and conduct the operation of tunnel emergency facilities for abnormal situations. It is also to be noted that tunnel operation is inseparable from tunnel emergency facilities. For example, the operation of a water sprinkler system is introduced to tackle a fire accident in a long tunnel with heavy traffic, and they can be operated properly only by adapting 24 hours operation system. Also, some systems can be operated and controlled effectively under the only limited situation. For example, a water sprinkler system can be used after a road administrator confirms that road users are evacuated from a tunnel as described in Section 3.5.2 (2). In this case, it is highly necessary to collect information inside tunnels properly, quickly, and timely, otherwise it may lead to the adverse operational effect.

In addition, it shall be required to develop an operation and maintenance plan of tunnels in cooperation with relevant authorities such as traffic police, fire defense agency, etc.

3.6.2 Classification of Tunnels

For the purpose of operation of tunnels and arrangement of emergency facilities, tunnels shall be classified into five grades (AA, A, B, C, and D) as shown in Figure 3-25 below.



[11]

Figure 3-25: Classification of Tunnels

Operation of tunnels and arrangement of emergency facilities shall be planned and conducted with comprehensive consideration of tunnel conditions such as tunnel length, alignment, design speed, traffic volume, traffic lanes and width, ventilation system, traffic direction (uni- or bi-), operation system, etc. as well as forecasted scale and frequency of a fire accident in a tunnel. However, the reality is very complicated and requires great effort to decide the tunnel operation and the facility arrangement in consideration of all factors mentioned above. In this sense, emergency facilities shall be standardized as much as possible for more user-friendliness. It is practical to standardize emergency facilities to be installed based on the tunnel grades in terms of both fire accidents and traffic accidents, although it is necessary to decide details by risk analysis.

Tunnel grades are determined by the possibility and scale of fire accidents and traffic accidents in tunnels. Practically two factors of tunnel length and traffic volume are used to categorize tunnel grades, as described in

Figure 3-25. Tunnels are classified by the factor tunnel length only in case traffic volume is less than 4,000 vehicles per day per tube, because evacuation, rescue, and fire-fighting conditions become more challenging if a tunnel has a longer length, even traffic volume is low.

Generally, the grade of a tunnel shall be decided by estimated traffic volume after 10 years of tunnel opening to the public, because almost all tunnel emergency facilities need to be replaced within 10 to 15 years, and it is also recommended to review the tunnel grade in every five years. Note that careful and independent decision and plan shall be required in case of 1) large-scale facilities such as water sprinklers, 2) facilities which affect the dimension of a tunnel itself such as inspection foot pass, water supply system, and 3) condition which gives a great impact for expected traffic volume such as the construction of an additional tunnel, construction of diversion route, etc.

In addition, it is necessary to consider up-gradation of tunnel classification if traffic accidents are forecasted much more than the normal tunnel, such as a tunnel with the small horizontal curve (e.g. less than 500m), with a long down gradient. It is also necessary to consider regarding multiple tunnels as continuous tunnel, if portals of the tunnels are closely located each other.

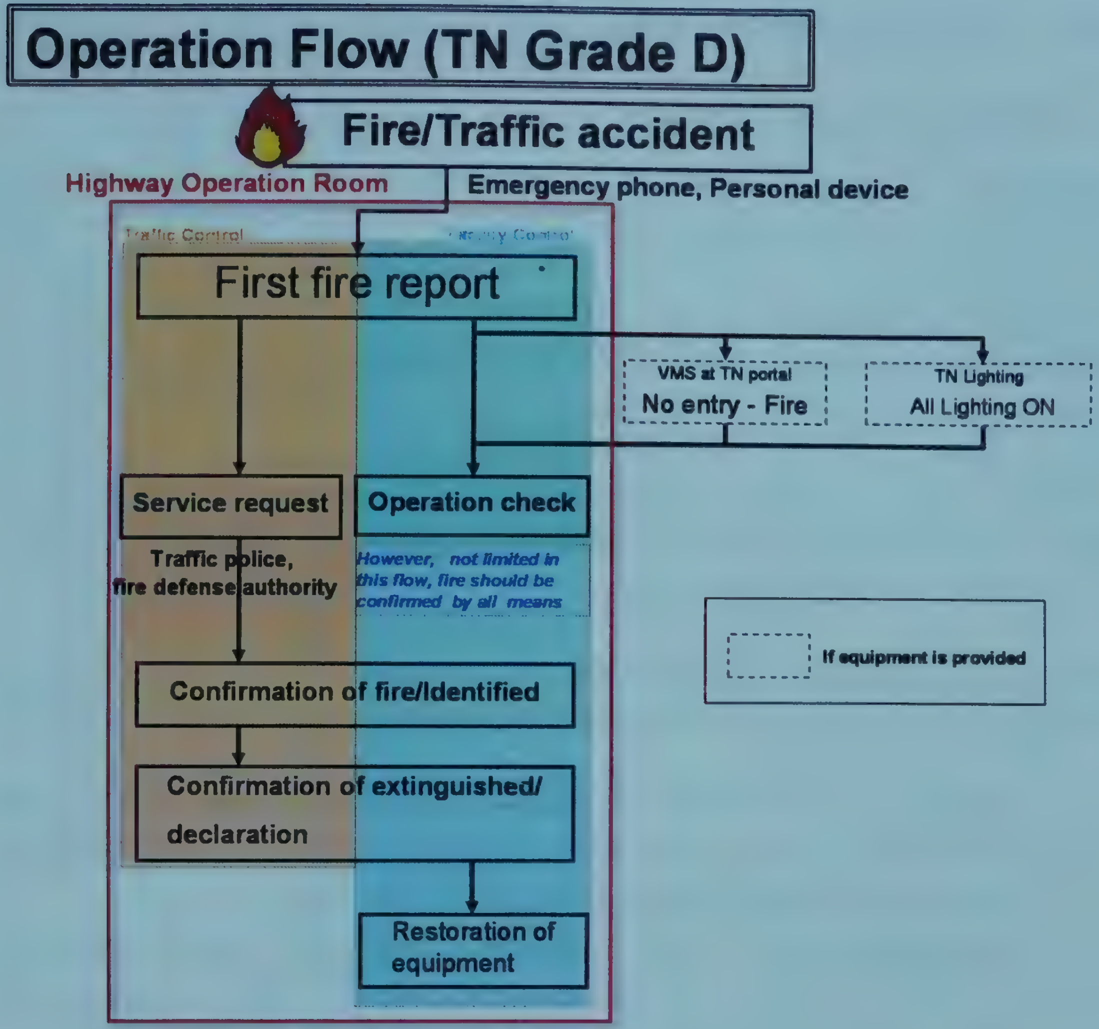
3.6.3 Operation of the Grade "D" Tunnel

(1) Outline of the Operation

The grade "D" is the lowest classification of tunnels, which length is between 100m (20,000vehicles/day/tube) and 500m (less than 4,000vehicles/day/tube). Generally, in grade "D" tunnels, the opposite side of a tunnel can be seen from another side, and the distance from the accident point to outside of the tunnel (i.e. tunnel portal) is short. Thus, simple operation and minimum arrangement of tunnel emergency facilities are sufficient for grade "D" tunnels.

Figure 3-26 describes the outline of the operation for grade "D" tunnels. Operation activities below shall be considered for grade "D" tunnels.

- ✓ Report: Fire/traffic accident is reported from a road user(s) to highway operation room (road administrator) by emergency phone and/or personal device (mobile phone etc.).
- ✓ Communication: The highway operation room informs relevant authorities (Traffic police, fire defense authority) and requests them to take necessary actions by general phone (landline, mobile phone).
- ✓ Alert: The highway operation room provides information of the accident through emergency information device (VMS) and regulates the traffic to enter the tunnel~~,~~ if provided.
- ✓ Initial fire-fighting: Road users conduct initial fire-fighting by fire extinguishers.
- ✓ Evacuation: The road users evacuate to the tunnel outside from the tunnel portals.
- ✓ Lighting: The highway operation room operates and turns on all lighting systems in the tunnel.
- ✓ Full-scale (secondary) fire-fighting: Fire defense authority who receives information from highway operation room conducts full-scale fire-fighting.


Operation Flow (TN Grade D)
Fire/Traffic accident
Highway Operation Room
Emergency phone, Personal device
Traffic Control
Facility Control
First fire report
VMS at TN portal
No entry - Fire
TN Lighting
All Lighting ON
Service request
Operation check
Traffic police,
fire defense authority
However, not limited in this flow, fire should be confirmed by all means
If equipment is provided
Confirmation of fire/Identified
Confirmation of extinguished/
declaration
Restoration of equipment

Source: JICA Expert Team

Figure 3-26: Operation for the Grade "D" Tunnel

(2) Arrangement of Tunnel Emergency Facilities

Table 3-4 shows the required tunnel emergency facilities for the grade "D" tunnel.

Table 3-4: Arrangement of Tunnel Emergency Facilities for the Grade "D" Tunnel

Tunnel Emergency Facilities			Arrangement
Report and alert facilities	Emergency phone		- Both portals - 200m interval
	Emergency information device	VMS at the tunnel portal	- Entrance of over 200m length tunnel
Fire-fighting facilities	Fire extinguisher		- 50m interval
Other facilities	Lighting during power failure		- Over 200m length tunnel
	Emergency power supply	UPS	- Over 200m length tunnel

Source: JICA Expert Team

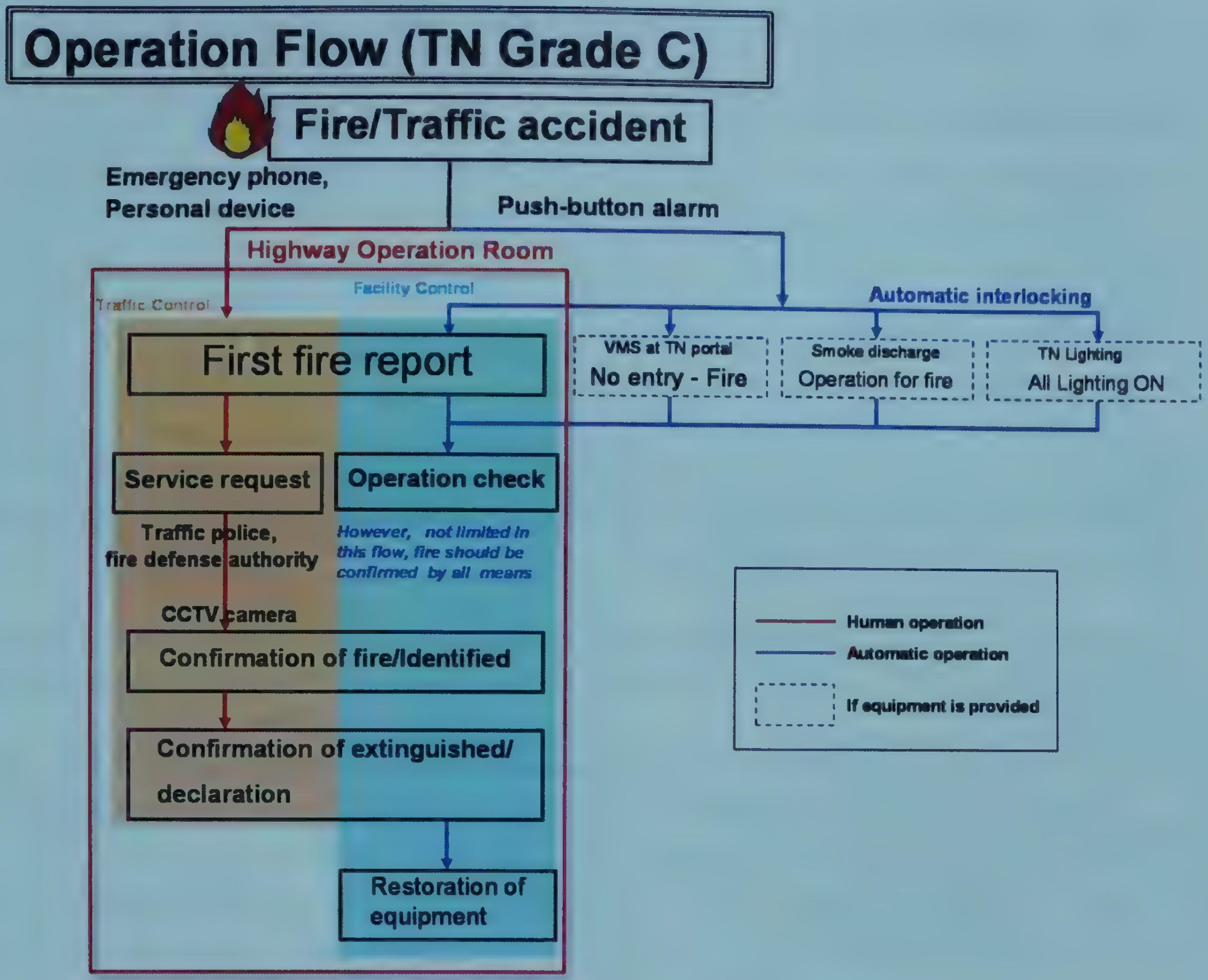
3.6.4 Operation of the Grade "C" Tunnel

(1) Outline of the Operation

The grade "C" is the 2nd lowest classification of tunnels, which length is between 100m (20,000 to 40,000 vehicles/day/tube) and 1,000m (less than 4,000 vehicles/day/tube). Generally, grade "C" tunnels are not equipped with escape tunnels, and evacuation time becomes longer than the grade "D" tunnel; therefore more quick operation becomes necessary, i.e. actions and activities, before road users evacuate to tunnel outside. Hence, a push-button alarm system shall be installed, which does not require a human operator to provide information to road users, i.e. VMS can provide information automatically by pushing the push-button alarm. Moreover, a smoke discharge system may be provided for a tunnel according to the chapter of tunnel facilities in "Guidelines for Tunnels", where necessary.

Figure 3-27 describes the outline of the operation for grade "C" tunnels. In the case of grade "C" tunnels, operation activities below shall be considered.

- ✓ Report: Fire/traffic accident is reported from a road user(s) to highway operation room (road administrator) by push-button alarm, emergency phone, and/or personal device (mobile phone, etc.).
- ✓ Communication: The highway operation room informs relevant authorities (Traffic police, fire defense authority) and requests them to take necessary actions by general phone (landline, mobile phone).
- ✓ Alert: Information about the accident is provided immediately and automatically through an emergency information device (VMS) after pushing the push-button alarm, and the traffic is regulated to enter the tunnel. The highway operation room monitors the information provided to road users and updated it if needed.
- ✓ Initial fire-fighting: The road users conduct initial fire-fighting by fire extinguishers.
- ✓ Smoke discharge: The smoke discharge system starts operation automatically and immediately after pushing the push-button alarm if provided. The highway operation room monitors the situation and changes and ends the operation if needed.
- ✓ Evacuation: Road users evacuate to the tunnel outside from the tunnel portals.
- ✓ Lighting: All lighting systems turn on in the tunnel automatically and immediately after pushing the push-button alarm. The highway operation room monitors the situation and changes and ends the operation if needed.
- ✓ Full-scale (secondary) fire-fighting: Fire defense authority who receives information from highway operation room conducts full-scale fire-fighting.


Operation Flow (TN Grade C)
Fire/Traffic accident
Emergency phone,
Personal device
Push-button alarm
Highway Operation Room
Traffic Control
Facility Control
Automatic interlocking
First fire report
VMS at TN portal
No entry - Fire
Smoke discharge
Operation for fire
TN Lighting
All Lighting ON
Service request
Operation check
Traffic police,
fire defense authority
However, not limited in this flow, fire should be confirmed by all means
CCTV camera
Confirmation of fire/Identified
Confirmation of extinguished/ declaration
Restoration of equipment
Human operation
Automatic operation
If equipment is provided

Source: JICA Expert Team

Figure 3-27: Operation for the Grade “C” Tunnel

(2) Arrangement of Tunnel Emergency Facilities

Table 3-5 shows the required tunnel emergency facilities for the grade “C” tunnel.

Table 3-5: Arrangement of Tunnel Emergency Facilities for the Grade “C” Tunnel

Tunnel Emergency Facilities			Arrangement
Report and alert facilities	Emergency phone		- Both portals - 200m interval
	Push-button alarm		- 50m interval
	Emergency information device	VMS at the tunnel portal	- Entrance of over 200m length tunnel
Fire-fighting facilities	Fire extinguisher		- 50m interval
Evacuation guide facilities	Smoke discharge system		- Refer to “Guideline for Tunnels”
Other facilities	Lighting during power failure		- Over 200m length tunnel
	Emergency power supply	Self-power generation system	- Over 500m length tunnel
		UPS	- Over 200m length tunnel

Source: JICA Expert Team

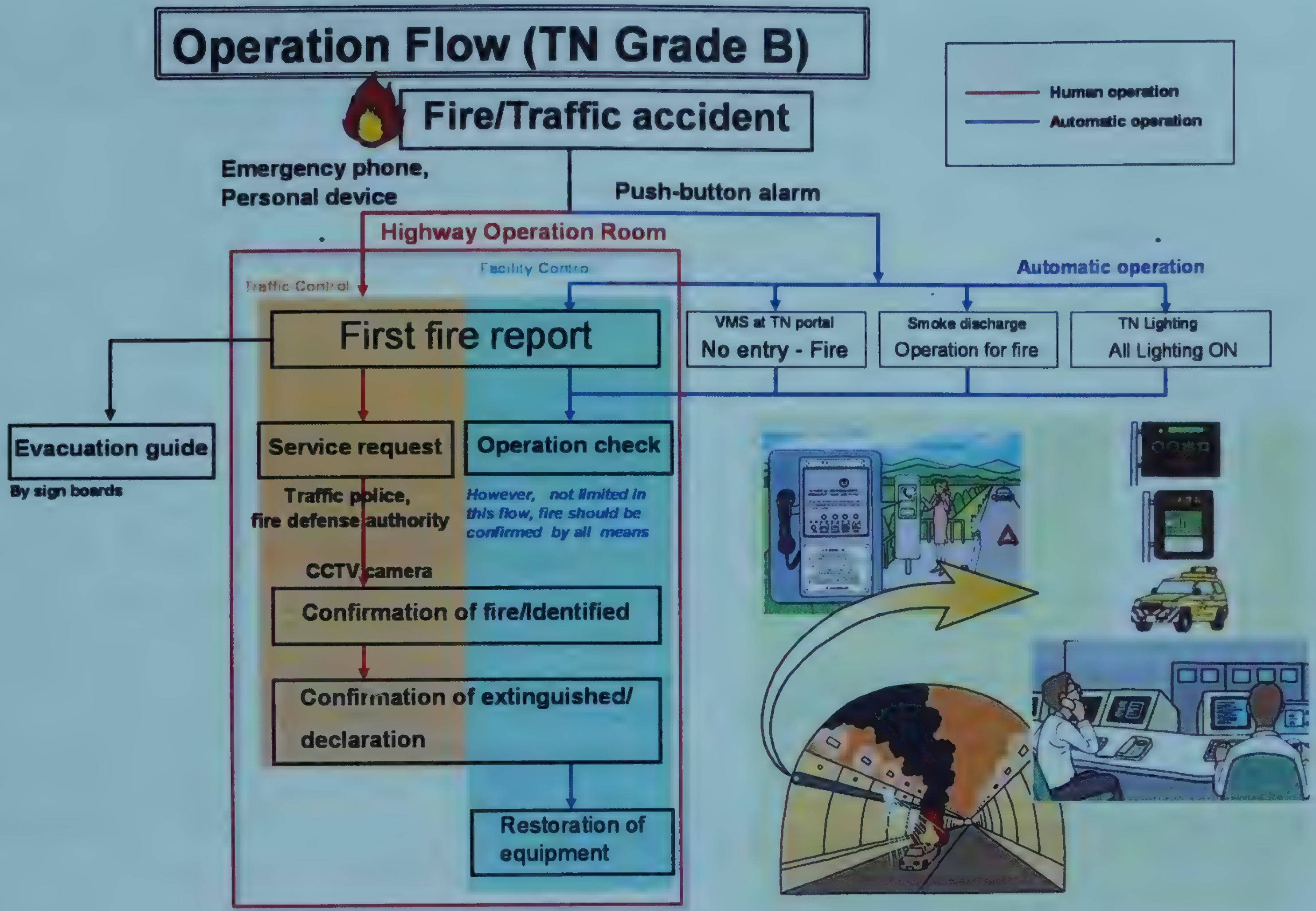
3.6.5 Operation of the Grade "B" Tunnel

(1) Outline of the Operation

The grade "B" is the middle classification of tunnels, which length is between 100m (40,000vehicles/day/tube) and 3,000m (less than 4,000vehicles/day/tube). Almost all of the tunnels in this grade are considered "Long Tunnel". It is required to strengthen the fire-fighting capacity of emergency facilities in this regard, especially for a tunnel with more than 1,000m in length. The evacuation routes become complicated because escape tunnels and exits are provided to a tunnel with 1,500m length according to the Guideline of Road Tunnels (IRC:SP:91). Therefore proper guidance to escape exits and tunnel portals shall be required. In addition, a smoke discharge system and monitoring system shall be provided for a tunnel with an escape tunnel to monitor an accident as well as to assist the evacuation of road users.

Figure 3-28 describes the outline of the operation for the grade "B" tunnel. In the case of the grade "B" tunnel, the operation activities below shall be considered.

- ✓ Report: Fire/traffic accident is reported from a road user(s) to highway operation room (road administrator) by push-button alarm, emergency phone, and/or personal device (mobile phone, etc.).
- ✓ Communication: The highway operation room informs relevant authorities (Traffic police, fire defense authority) and requests them to take necessary actions by general phone (landline, mobile phone).
- ✓ Alert: Information about the accident is provided immediately and automatically through emergency information devise (VMS) after pushing the push-button alarm, and the traffic is regulated to enter the tunnel. The highway operation room monitors the information provided to road users and updated it if needed.
- ✓ Initial fire-fighting: Road users conduct initial fire-fighting by fire extinguishers and fire hydrants.
- ✓ Smoke discharge: The smoke discharge system starts its operation automatically and immediately after pushing the push-button alarm. The highway operation room monitors the situation, change, and end the operation if needed.
- ✓ Monitoring: Highway operation room mainly monitors the situation of the evacuation of road users through CCTV cameras.
- ✓ Evacuation: Road users evacuate to the tunnel outside from the tunnel portals and the escape tunnel. Evacuation routes are guided through guide signboards.
- ✓ Lighting: All lighting systems are turned on in the tunnel automatically and immediately after pushing the push-button alarm. The highway operation room monitors the situation, change, and end the operation if needed.
- ✓ Full-scale (secondary) fire-fighting: Fire defense authority who receives information from highway operation room conducts full-scale fire-fighting. Hydrants assist their fire-fighting activities.


Operation Flow (TN Grade B)
Fire/Traffic accident
Human operation
Automatic operation
Emergency phone, Personal device
Push-button alarm
Highway Operation Room
Traffic Control
Facility Control
Automatic operation
First fire report
VMS at TN portal
No entry - Fire
Smoke discharge
Operation for fire
TN Lighting
All Lighting ON
Evacuation guide
By sign boards
Service request
Operation check
Traffic police, fire defense authority
However, not limited in this flow, fire should be confirmed by all means
CCTV camera
Confirmation of fire/Identified
Confirmation of extinguished/ declaration
Restoration of equipment

Source: JICA Expert Team

Figure 3-28: Operation for the Grade "B" Tunnel

(2) Arrangement of Tunnel Emergency Facilities

Table 3-6 shows the required tunnel emergency facilities for the grade "B" tunnel.

Table 3-6: Arrangement of Tunnel Emergency Facilities for the Grade "B" Tunnel

Tunnel Emergency Facilities			Arrangement
Report and alert facilities	Emergency phone		- Both portals - 200m interval
	Push-button alarm		- 50m interval
	Emergency information device	VMS at the tunnel portal	- Entrance of over 200m length tunnel
Fire-fighting facilities	Fire extinguisher		- 50m interval
	Fire hydrant		- Over 1,000m length tunnel - 50m interval
	Hydrant		- Over 1,000m length tunnel - 200m interval
Evacuation guide facilities	Guide sign board	Emergency exit display	- Tunnel with an escape tunnel - Both side walls at emergency exits
		Guide sign board	- Tunnel with an escape tunnel - Escape tunnel - 200m interval on both side walls
		Emergency exit guide sign board	- Tunnel with an escape tunnel - Opposite side wall at emergency exits
	Smoke discharge system	Smoke discharge facility	- Refer to "Guideline for Tunnels"
	Evacuation route	Escape tunnel	- Refer to the Guideline of Road Tunnels (IRC:SP:91-2010)
		Connection tunnel	
Monitoring facilities	CCTV cameras	Type B	- Emergency exits (parking bays)
Other facilities	Lighting during power failure		- Over 200m length tunnel
	Emergency power supply	Self-power generation system	- Over 500m length tunnel
		UPS	- Over 200m length tunnel

Source: JICA Expert Team

(3) Operation of Smoke Discharge System

In the case of uni-direction tunnels, vehicles running ahead of a fire/traffic accident can keep running and go out from a tunnel; however, vehicles running toward a fire/traffic accident are expected to have no choice but to stay in a tunnel longer time, because they cannot move forward and may also be involved in the accident or secondary accidents. Therefore, a smoke discharge system shall be operated to discharge smoke and gases from the portal ahead, i.e. the moving direction of vehicles. It shall be also required that the wind velocity by smoke discharge system is more than the velocity by natural wind (ventilation) which is generally 2m per second.

In the case of bi-direction tunnels, vehicles are pooled on both sites of an accident location. Therefore, it is necessary to prevent diffusion of smoke/gases and secure evacuation environment for road users by smoke discharge system (and ventilation system, if provided separately).

If a bi-direction tunnel is equipped with a longitudinal ventilation system and is the grade "AA" or more than 3,000m lengths with more than 4,000 vehicles per day of traffic volume, it is recommended to apply the "Lower Wind Velocity Control" method.

This method aims to operate a smoke discharge system (and ventilation system) so that wind velocity in a tunnel is reduced to less than 2m per second and close to 0 (zero) as much as possible within 90 seconds after the detection of a fire accident.

3.6.6 Operation of the Grade "A" Tunnel

(1) Outline of the Operation

The grade "A" is the 2nd highest classification of tunnels, which length is between 300m (40,000vehicles/day/tube) and 10,000m (less than 4,000vehicles/day/tube). Almost all of the tunnels in this grade are considered "Long Tunnel". The situation of a fire/traffic accident becomes severe easily if a proper operation is not conducted, especially more than 3,000m lengths of a tunnel. Therefore it is required to strengthen the fire-fighting capacity of emergency facilities, especially water sprinkler is required to be provided for the tunnel with severe condition (more than 3,000m in length and more than 4,000vehicles per day per tube of traffic volume). Also, evacuation routes become more complicated, especially for a tunnel with more than 3,000m lengths, hence proper guidance to escape exits and tunnel portals shall be required not only by sign boards but also by sound (voice) equipment. In addition, a smoke discharge system and monitoring system shall be provided to a tunnel with escape tunnel to monitor an accident as well as to assist the evacuation of road users. An additional monitoring system shall be provided to monitor the evacuation of road users in a tunnel for proper operation of the water sprinkler.

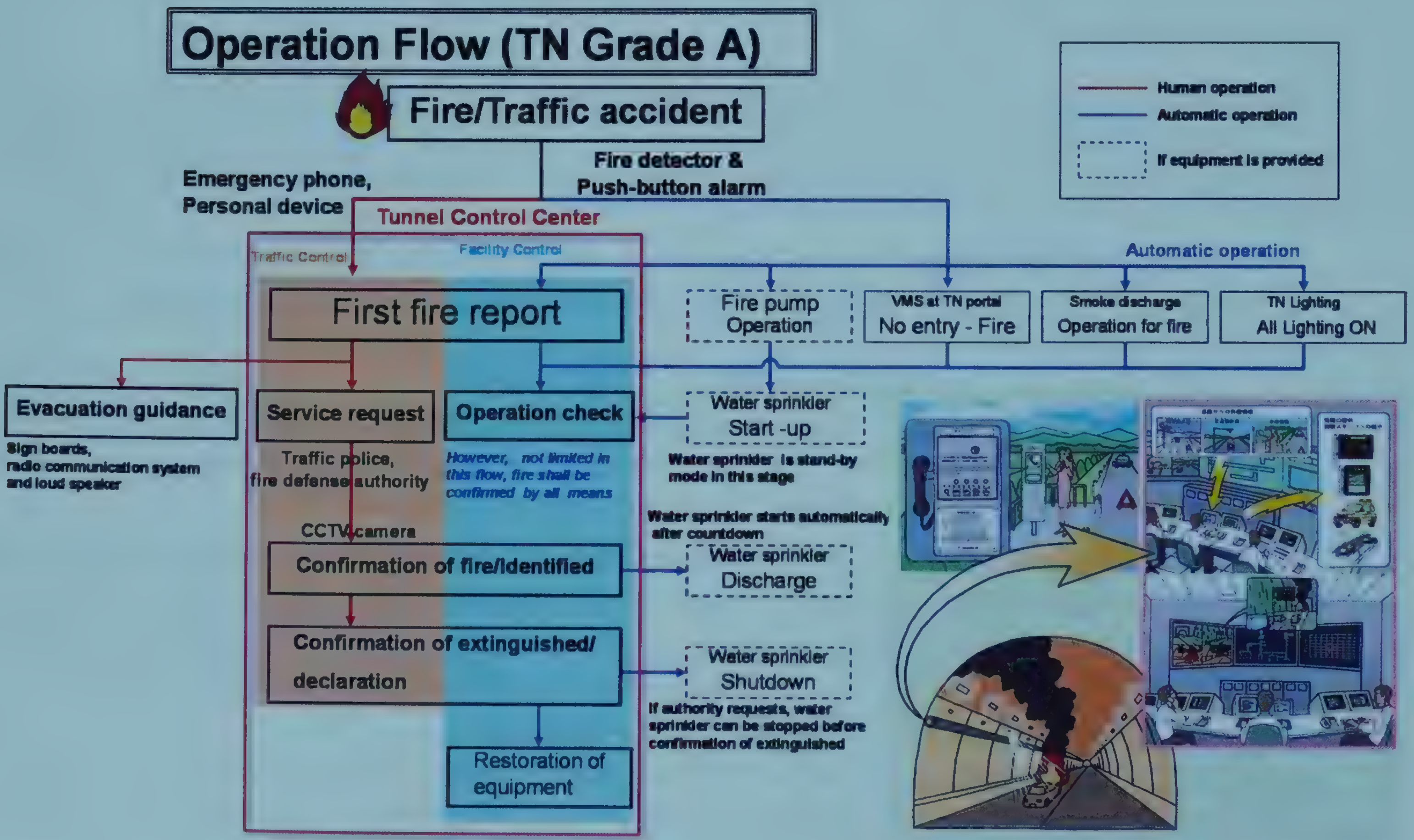
Taking account of intensive and complicated operations necessary for grade "A" tunnels, a dedicated tunnel control center apart from the highway operation room shall be established on a 24 hours operation basis for a tunnel with 3,000m length.

Figure 3-29 describes the outline of the operation for the grade "A" tunnel. In the case of grade "A" tunnels, the operation activities below can be considered.

- ✓ Report: Fire/traffic accident is automatically and immediately detected by fire detector. And it is also reported from a road user(s) to the highway operation room or tunnel control center (if established) by push-button alarm, emergency phone, and/or personal device (mobile phone, etc.).
- ✓ Communication: The highway operation room or tunnel control center (if established) informs relevant authorities (Traffic police, fire defense authority) and requests them to take necessary actions by general phone (landline, mobile phone). Preferably relevant agencies work together with road administrators in the tunnel control center if established.
- ✓ Alert: Information about the accident is provided immediately and automatically through an emergency information device (VMS) after detecting the accident by fire detector or push-button alarm, and the traffic is strictly regulated to enter the tunnel by VMS and traffic signal~~,~~ if provided. The highway operation room or tunnel control center (if established) monitors the information provided to road users and updated it if needed.
- ✓ Initial fire-fighting: Road users conduct initial fire-fighting by fire extinguishers and fire hydrants. Road administrator starts operation of water sprinkler (if provided) after confirming evacuation of road users.
- ✓ Smoke discharge: The smoke discharge system starts its operation automatically and immediately after detecting the accident by fire detector or push-button

alarm. The highway operation room or tunnel control center (if established) monitors the situation and change and end the operation if needed.

- ✓ Monitoring: The highway operation room or tunnel control center (if established) mainly monitors the situation of the evacuation of road users through CCTV cameras. The CCTV camera(s) automatically lock(s) on the accident, and the accident is also monitored.
- ✓ Evacuation: Road users evacuate to the tunnel outside from the tunnel portals and the escape tunnel. Evacuation routes are guided through guide sign boards, radio communication systems and loud speakers.
- ✓ Lighting: All lighting systems turn on in the tunnel automatically and immediately after detecting the accident by fire detector or push-button alarm. The highway operation room or tunnel control center (if established) monitors the situation and change and end the operation if needed.
- ✓ Full-scale (secondary) fire-fighting: Fire defense authority who receives information from highway operation room or tunnel control center (if established) conducts full-scale fire-fighting. Hydrants assist their fire-fighting activities. Also, fire defense authority or road administrator communicates with tunnel inside by emergency phones at tunnel portal, if provided.


Operation Flow (TN Grade A)
Fire/Traffic accident
Human operation
Automatic operation
If equipment is provided
Emergency phone, Personal device
Fire detector & Push-button alarm
Tunnel Control Center
Traffic Control
Facility Control
Automatic operation
First fire report
Fire pump Operation
VMS at TN portal
No entry - Fire
Smoke discharge
Operation for fire
TN Lighting
All Lighting ON
Evacuation guidance
Sign boards, radio communication system and loud speaker
Service request
Traffic police, fire defense authority
Operation check
However, not limited in this flow, fire shall be confirmed by all means
Water sprinkler Start -up
Water sprinkler is stand-by mode in this stage
Water sprinkler starts automatically after countdown
CCTV camera
Confirmation of fire/Identified
Water sprinkler Discharge
Confirmation of extinguished/ declaration
Water sprinkler Shutdown
If authority requests, water sprinkler can be stopped before confirmation of extinguished
Restoration of equipment

Source: JICA Expert Team

Figure 3-29: Operation for the Grade "A" Tunnel

(2) Arrangement of Tunnel Emergency Facilities

Table 3-7 shows the required tunnel emergency facilities for the grade "A" tunnel.

Table 3-7: Arrangement of Tunnel Emergency Facilities for the Grade "A" Tunnel

Tunnel Emergency Facilities			Arrangement
Report and alert facilities	Emergency phone		- Both portals - 200m interval
	Push-button alarm		- 50m interval
	Fire detector		- Tunnel with smoke discharge system - 25 to 50m interval
	Emergency information device	VMS at the tunnel portal	- Entrance of a tunnel
		VMS at tunnel inside	- Over 3,000m length tunnel - Parking bays
	Traffic Signal		- Entrance of over 3,000m length tunnel
Fire-fighting facilities	Fire extinguisher		- 50m interval
	Fire hydrant		- 50m interval
	Hydrant		- 200m interval
	Water sprinkler		- Over 3,000m length tunnel with 4,000vehicles/day - Whole length of a tunnel
Evacuation guide facilities	Guide sign board	Emergency exit display	- Tunnel with an escape tunnel - Both side walls at emergency exits
		Guide sign board	- Tunnel with an escape tunnel - Escape tunnel - 200m interval on both side walls
		Emergency exit guide sign board	- Tunnel with an escape tunnel - Opposite side wall at emergency exits
	Smoke discharge system	Smoke discharge facility	- Refer to "Guideline for Tunnels"
	Evacuation route	Escape tunnel	- Refer to the Guideline of Road Tunnels (IRC:SP:91-2010)
		Connection tunnel	
Communication facilities	Radio communication	Leaky coaxial cable	- Over 3,000m length tunnel - Whole length of a tunnel
		Emergency phone at the tunnel portal	- Both portals
	Radio re-broadcasting		- Over 3,000m length tunnel - Whole length of a tunnel
	Loudspeaker		- Tunnel with radio re-broadcasting - Escape tunnel - Both portals, emergency exits (parking bays)
Monitoring facilities	CCTV cameras	Type A	- Tunnel with water sprinkler - 120 to 200m interval
		Type B	- Emergency exits (parking bays)
Other facilities	Lighting during power failure		- Provided
	Emergency power supply	Self-power generation system	- Provided
		UPS	- Provided

Source: JICA Expert Team

3.6.7 Operation of the Grade "AA" Tunnel

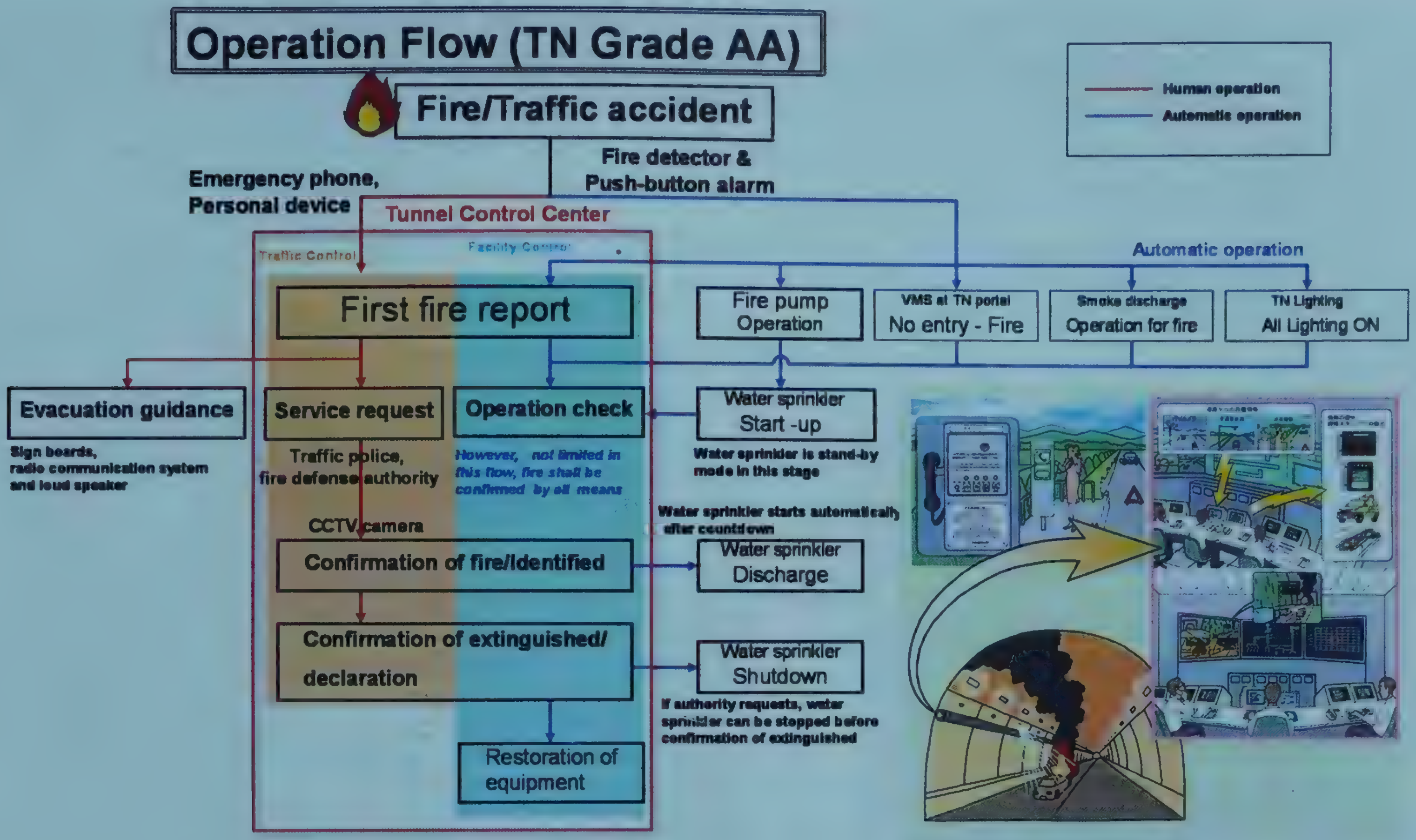
(1) Outline of the Operation

The grade "AA" is the highest classification of tunnels, which length is between 1,000m (40,000vehicles/day/tube) and over 10,000m (less than 4,000vehicles/day/tube). All tunnels in this grade are categorized into "Long Tunnel", and the conceivable full scale tunnel emergency facilities need to be provided as well as tunnel operation needs to be conducted.

Hence, a dedicated tunnel control center apart from the highway operation room shall be established on 24 hours operation for this grade tunnels.

Figure 3-30 describes outline of the operation for grade "AA" tunnels. In case of grade "AA" tunnels, the operation activities below can be considered.

- ✓ Report: Fire/traffic accident is automatically and immediately detected by fire detector. It is also reported from a road user(s) to tunnel control center by push-button alarm, emergency phone, and/or personal device (mobile phone, etc.).
- ✓ Communication: The tunnel control center informs relevant authorities (Traffic police, fire defense authority) and requests them to take necessary actions by general phone (landline, mobile phone). Preferably relevant agencies work together with road administrators in the tunnel control center.
- ✓ Alert: Information of accident is provided immediately and automatically through emergency information devise (VMS) after detecting the accident by fire detector or push-button alarm, and the traffic is strictly regulated to enter the tunnel by VMS and traffic signal. The tunnel control center monitors the information provided to road users and updated it if needed.
- ✓ Initial fire-fighting: Road user(s) conduct(s) initial fire-fighting by fire extinguishers and fire hydrants. Road administrator starts operation of water sprinkler after confirming evacuation of road users.
- ✓ Smoke discharge: The smoke discharge system starts the operation automatically and immediately after detecting the accident by fire detector or push-button alarm. The tunnel control center monitors the situation and change and end the operation if needed.
- ✓ Monitoring: The CCTV camera(s) nearby the accident automatically lock(s) on the accident, and the tunnel control center monitors the situation of the evacuation of road users and the accident through CCTV cameras.
- ✓ Evacuation: Road users evacuate to the tunnel outside from the tunnel portals and the escape tunnel. Evacuation routes are guided through guide sign boards, radio communication systems, and loudspeakers.
- ✓ Lighting: All lighting systems turn on in the tunnel automatically and immediately after detecting the accident by fire detector or push-button alarm. The tunnel control center monitors the situation and change and end the operation if needed.
- ✓ Full-scale (secondary) fire-fighting: Fire defense authority who receives information from tunnel control center conducts full-scale fire-fighting. Hydrants assist their fire-fighting activities. The fire defense authority or road administrator communicates with the tunnel inside by emergency phones at the tunnel portal.


Operation Flow (TN Grade AA)
Fire/Traffic accident
Human operation
Automatic operation
Emergency phone,
Personal device
Fire detector &
Push-button alarm
Tunnel Control Center
Traffic Control
Facility Control
Automatic operation
First fire report
Fire pump Operation
VMS at TN portal
No entry - Fire
Smoke discharge
Operation for fire
TN Lighting
All Lighting ON
Evacuation guidance
Sign boards,
radio communication system
and loud speaker
Service request
Traffic police,
fire defense authority
Operation check
However, not limited in this flow, fire shall be confirmed by all means
Water sprinkler Start -up
Water sprinkler is stand-by mode in this stage
Water sprinkler starts automatically after countdown
CCTV camera
Confirmation of fire/Identified
Water sprinkler Discharge
Confirmation of extinguished/ declaration
Water sprinkler Shutdown
If authority requests, water sprinkler can be stopped before confirmation of extinguished
Restoration of equipment

Source: JICA Expert Team

Figure 3-30: Operation for the Grade "AA" Tunnel

(2) Arrangement of Tunnel Emergency Facilities

Table 3-8 shows the required tunnel emergency facilities for grade "AA" tunnels.

Table 3-8: Arrangement of Tunnel Emergency Facilities for the Grade "AA" Tunnel

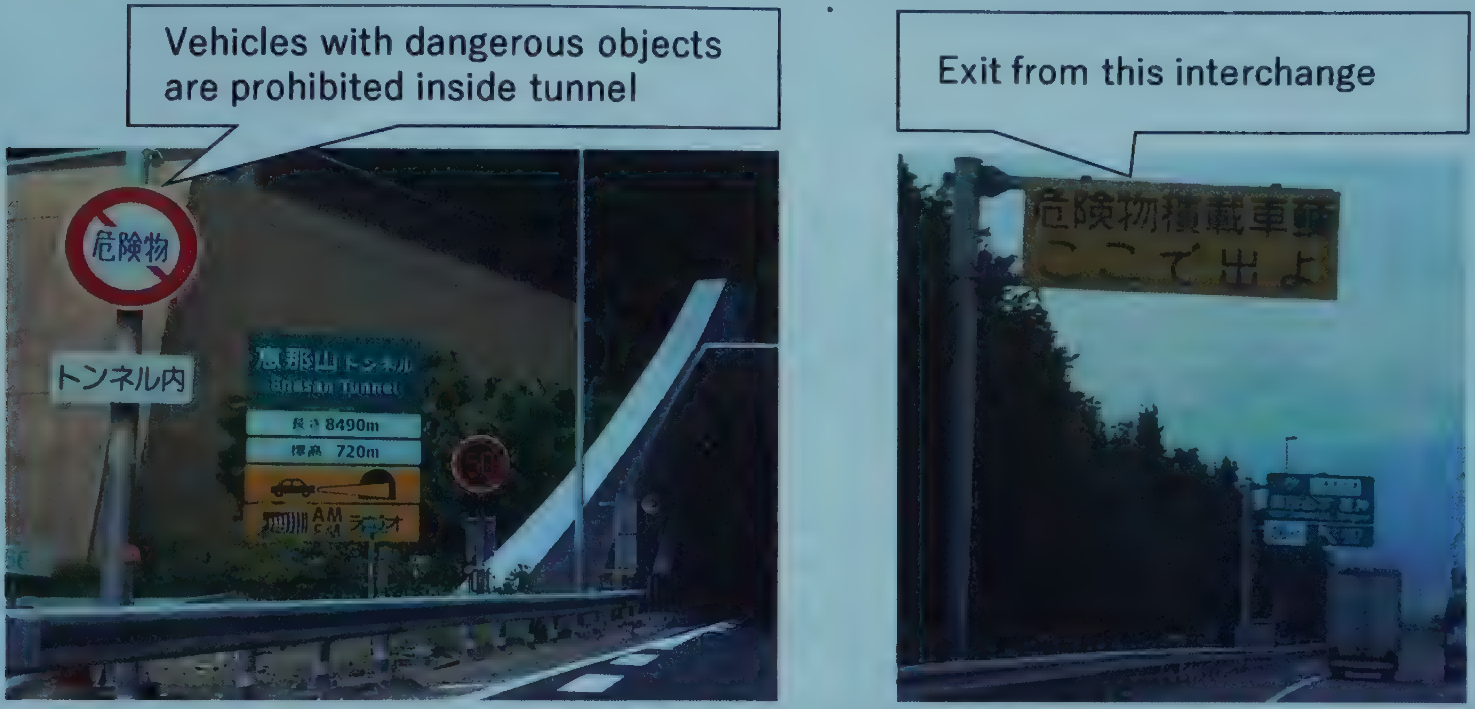
Tunnel Emergency Facilities			Arrangement
Report and alert facilities	Emergency phone		- Both portals - 200m interval
	Push-button alarm		- 50m interval
	Fire detector		- 25 to 50m interval
	Emergency information device	VMS at the tunnel portal	- Entrance of a tunnel
		VMS at tunnel inside	- Parking bays
	Traffic Signal		- Entrance of a tunnel
Fire-fighting facilities	Fire extinguisher		- 50m interval
	Fire hydrant		- 50m interval
	Hydrant		- 200m interval
	Water sprinkler		- Whole length of a tunnel
Evacuation guide facilities	Guide sign board	Emergency exit display	- Both side walls at emergency exits
		Guide sign board	- Main tunnel and escape tunnel - 200m interval on both side walls
		Emergency exit guide sign board	- Opposite side wall at emergency exits
	Smoke discharge system	Smoke discharge facility	- Provided - Refer to "Guideline for Tunnels"
	Evacuation route	Escape tunnel	- Provided
		Connection tunnel	
Communication facilities	Radio communication	Leaky coaxial cable	- Whole length of a tunnel
		Emergency phone at the tunnel portal	- Both portals
	Radio re-broadcasting		- Whole length of a tunnel
	Loudspeaker		- Both portals, emergency exits (parking bays) - Escape tunnel
Monitoring facilities	CCTV cameras	Type A	- 120 to 200m interval
		Type B	- Emergency exits (parking bays)
Other facilities	Lighting during power failure		- Provided
	Emergency power supply	Self-power generation system	- Provided
		UPS	- Provided

Source: JICA Expert Team

3.6.8 Passage of Vehicles with Dangerous Objects

Article 46-3 of the Japanese Road Traffic Act principally prohibits vehicles with dangerous objects from passing long tunnels which length is more than 5,000m, submerged tunnels, and tunnels adjacent to the water surface in order to secure road safety. Vehicles subject to this article need to take other routes to avoid such sections. Dangerous objects include oil, petroleum, explosives, poisonous materials, high-pressure gas, and etc. An example type of vehicle is tank truck.

To inform road users of passage prohibition, a road operator shall install traffic signs well upstream of a concerned tunnel. Figure 3-31 shows typical examples of such signs in Japan. Figure 3-32 shows an example of Kan-etsu tunnel on Kan-etsu expressway and NH17, where vehicles with dangerous objects are prohibited to pass Kan-etsu tunnel (tunnel length:11km) and requested to make a detour to National Highway 17 (NH17).



Vehicles with dangerous objects are prohibited inside tunnel

Exit from this interchange

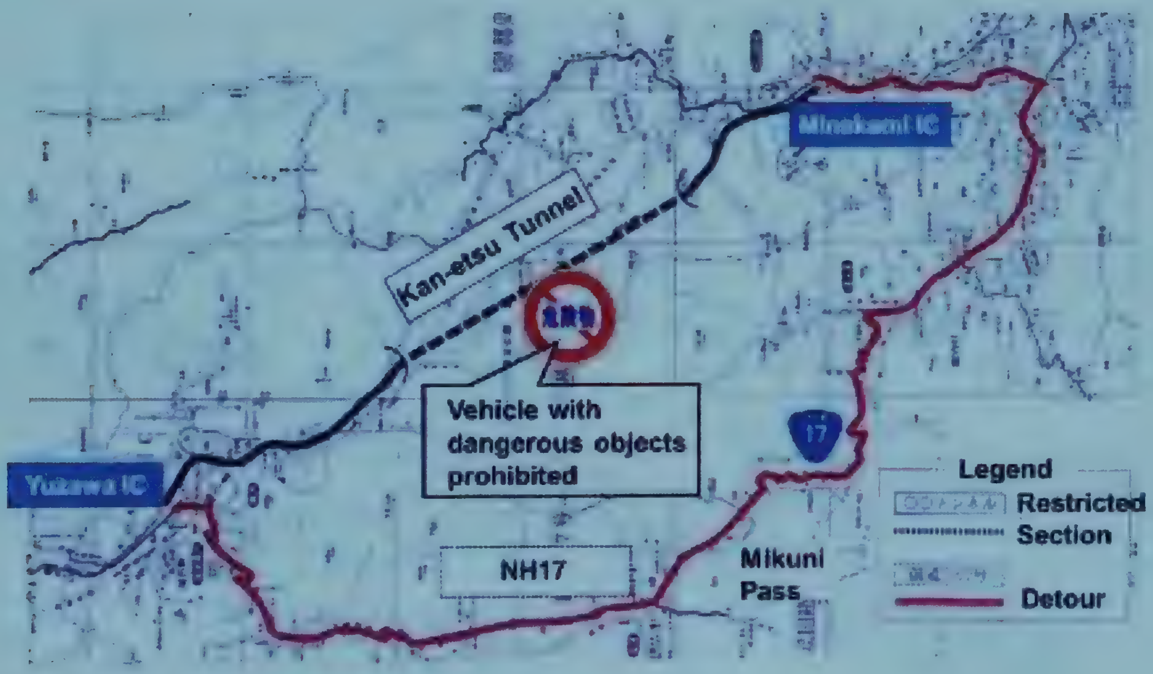
危険物
トンネル内
恵那山トンネル
Enasan Tunnel
長さ 8490m
標高 720m
AM ラジオ
危険物積載車輛
ここで出よ

(a) Sign in front of a Tunnel Portal

(b) Sign Upstream of a Tunnel Section

[12]

Figure 3-31: Examples of Traffic Signs to Inform Prohibition of Passage of Vehicles with Dangerous Objects



Vehicle with dangerous objects prohibited

Minakami IC
Kan-etsu Tunnel
危険物
Yuzawa IC
17
NH17
Mikuni Pass
Legend
Restricted Section
Detour

[12]

Figure 3-32: Examples of Kan-etsu tunnel on Kan-etsu Expressway and NH17

Amid the prohibition of the passage of dangerous vehicles, the Japanese Road Traffic Act has been recently reformed to allow the passage of tank trucks carrying oils or gas only at the time of large-scale national disaster to enhance energy transport to disaster-affected regions. For securing safety travel in a tunnel section, "Escort passage method" or equivalent methods shall be adapted. The detail of the “Escort passage method” is described in Figure 3-33 and Figure 3-34.

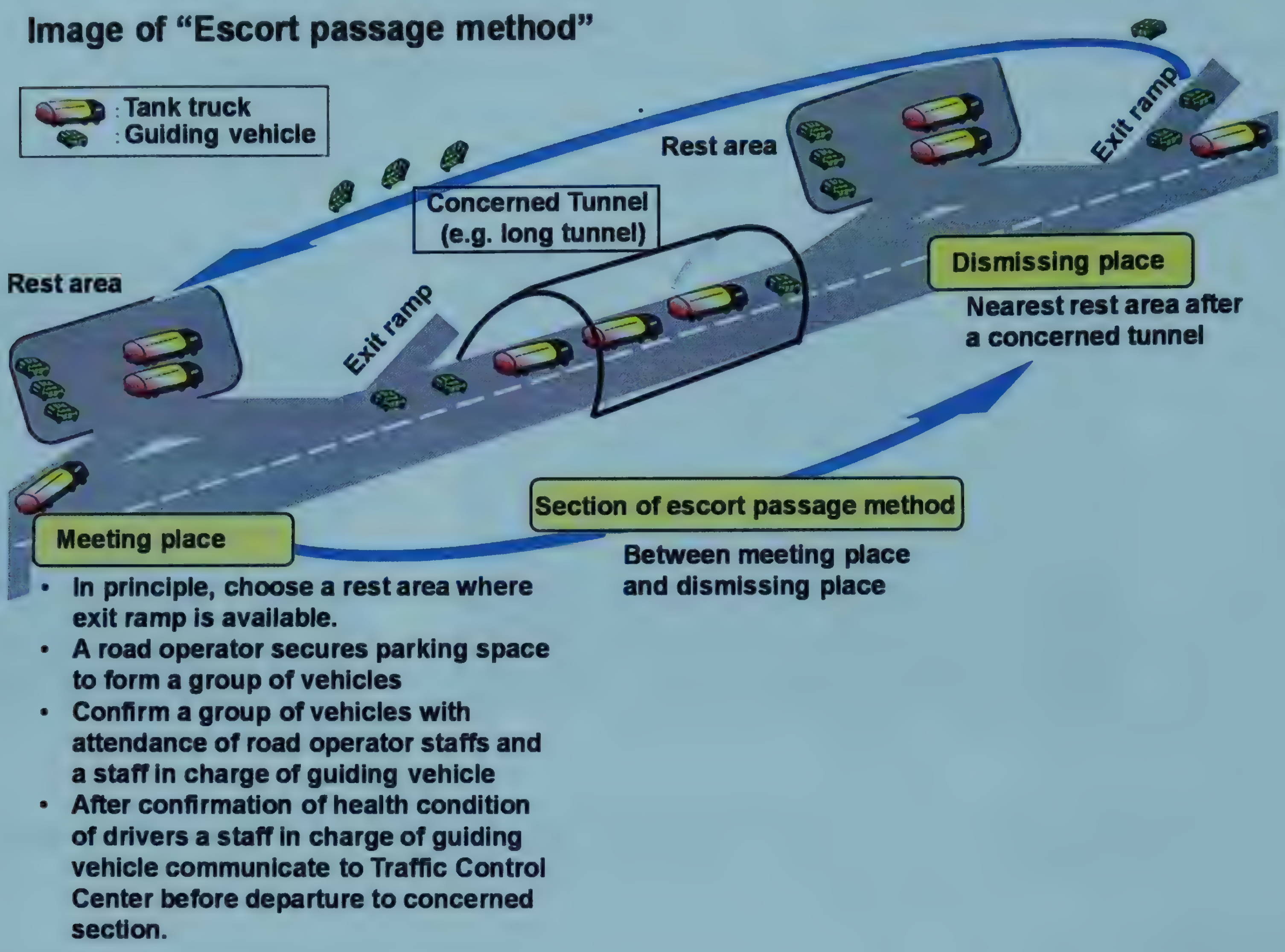


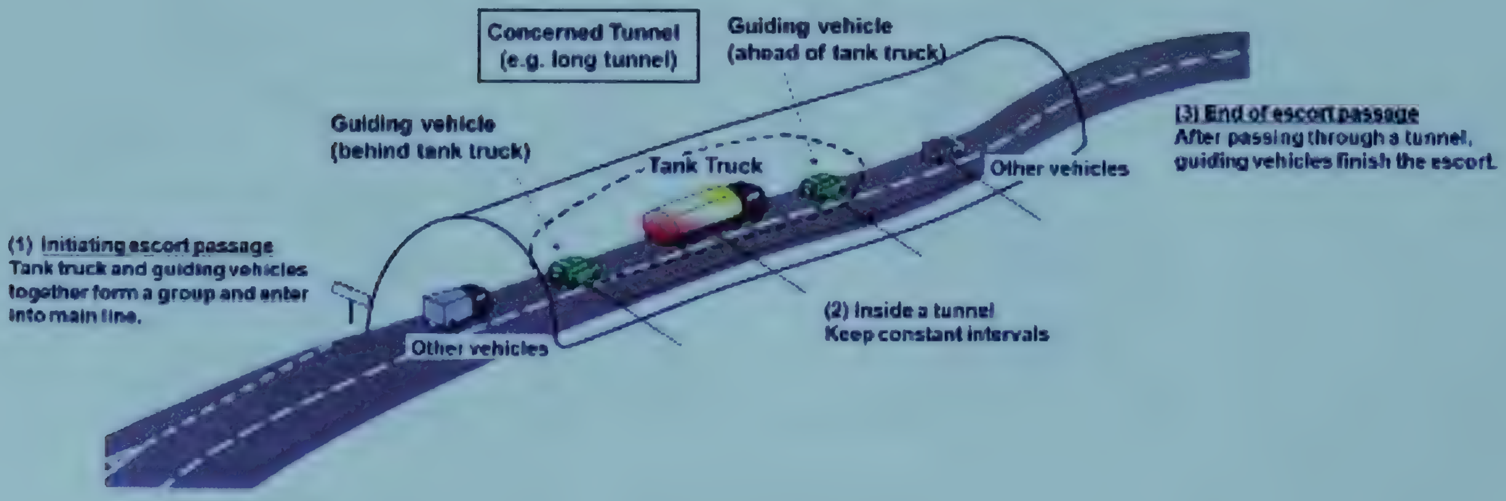
Image of “Escort passage method”

: Tank truck
: Guiding vehicle
Rest area
Concerned Tunnel (e.g. long tunnel)
Rest area
Exit ramp
Exit ramp
Dismissing place
Nearest rest area after a concerned tunnel
Section of escort passage method
Meeting place
Between meeting place and dismissing place

- In principle, choose a rest area where exit ramp is available.
- A road operator secures parking space to form a group of vehicles
- Confirm a group of vehicles with attendance of road operator staffs and a staff in charge of guiding vehicle
- After confirmation of health condition of drivers a staff in charge of guiding vehicle communicate to Traffic Control Center before departure to concerned section.

[12]

Figure 3-33: Image of “Escort Passage Method”



Concerned Tunnel (e.g. long tunnel)
Guiding vehicle (ahead of tank truck)
Guiding vehicle (behind tank truck)
Tank Truck
Other vehicles
Other vehicles

(1) Initiating escort passage
Tank truck and guiding vehicles together form a group and enter into main line.

(2) Inside a tunnel
Keep constant intervals

(3) End of escort passage
After passing through a tunnel, guiding vehicles finish the escort.

[12]

Figure 3-34: Detail of “Escort Passage Method”

3.7 Tunnel Control Center

3.7.1 Outline of Tunnel Control Center

As shown in the section above, proper disaster management shall be required to protect the life of road users including a person who causes an accident as well as to prevent the expansion of damages after the accident. In case of a fire accident, procedures of proper disaster management when a fire accident occurs are 1) to 5), as below:

1) Report: road administrator receives information of a fire accident from road users through reporting facilities such as emergency phone etc.
2) Communication: road administrator informs relevant authorities (Traffic police, fire defense authority) and requests them to take necessary actions
3) Alert: road administrator informs other road users about a fire accident through alert facilities such as VMS
4) Initial fire-fighting: road users extinguish a fire using fire-fighting facilities such as fire extinguishers etc.
5) Evacuation: road administrator guides road users to evacuate from an inside tunnel inside. Full-scale (secondary) fire-fighting by fire defense authority and traffic regulation by traffic police are also very important actions to minimize the scale and damage of a fire accident as well as to avoid other road users involved in a fire accident; therefore road administrator needs to assist these activities as much as possible.

In this point of view, in order to proceed with proper disaster management actions under an emergency situation, it is required to establish a "Center Commando" for the operation of a tunnel. Especially, "Tunnel Control Center" shall be established to a tunnel which length exceeds 1,500m and is AA and A ranks, because many tunnel emergency facilities are installed, evacuation route becomes complicated by providing emergency exits and also more strict tunnel emergency management is required.

3.7.2 Roles of Tunnel Control Center

A tunnel control center shall have the facility control function. A function of the tunnel control center is summarized in Table 3-9, and an image photograph of a facility control center is shown in Figure 3-35.

Table 3-9: Main Roles of Tunnel Control Center

Function	Contents
Facility control function	✓ Monitoring of tunnel emergency facilities in a tunnel and collecting information from them ✓ Responses to emergency situations including a fire accident in a tunnel (control of the emergency facilities in a tunnel) ✓ Monitoring and responses to breakdown and abnormalities of road facilities (including tunnel emergency facilities in a tunnel and tollgate)

Source: JICA Expert Team

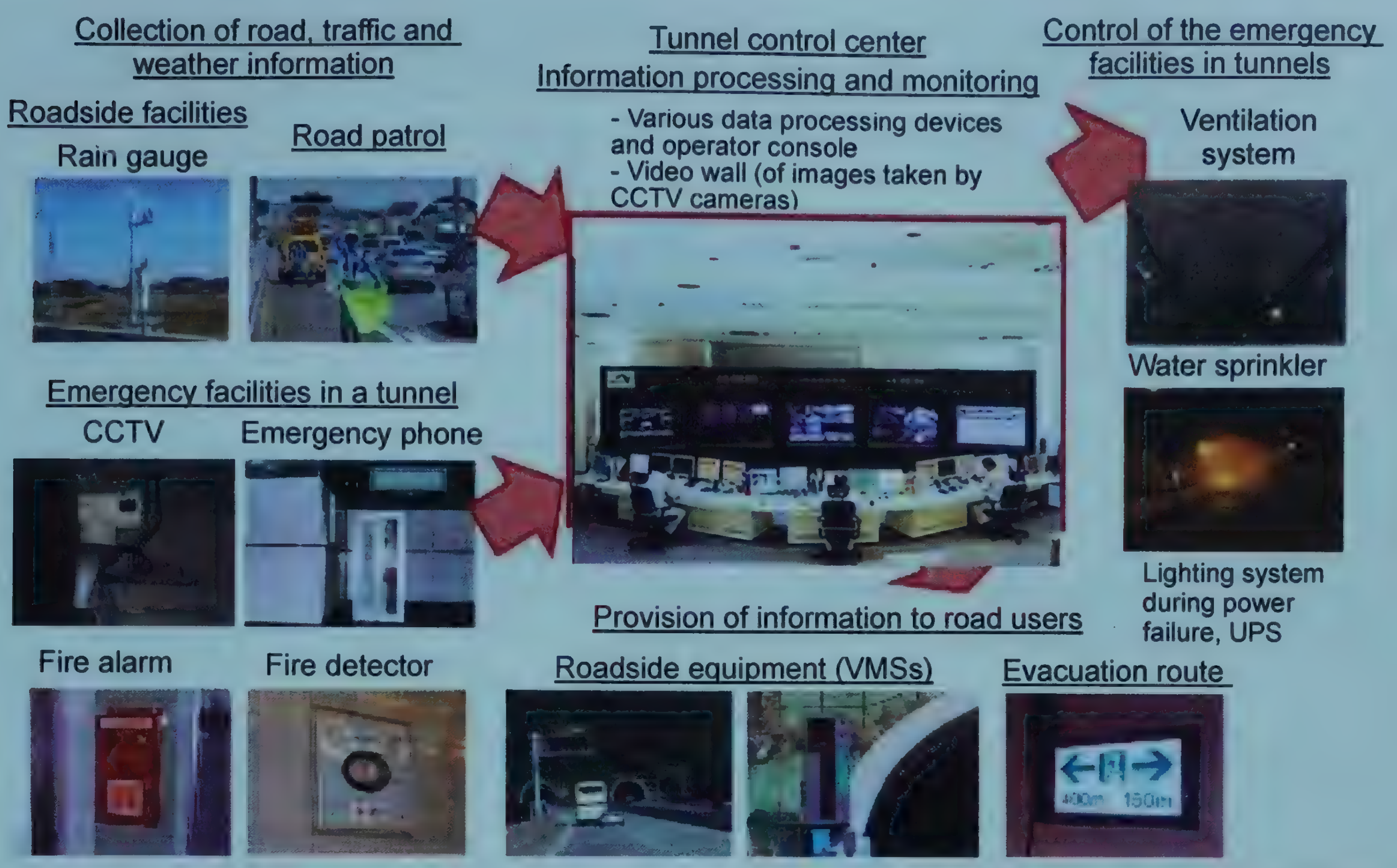
Source: JICA Expert Team

Figure 3-35: Tunnel Control Center

3.7.3 Works at Tunnel Control Center

Figure 3-36 shows an outline of works at the tunnel control center. All the collected road traffic information related to the tunnel are sent to the tunnel control center and used for the real-time monitoring of tunnel condition. This information is also analyzed and accumulated. When an emergency situation such as an accident or a fire accident has occurred in a tunnel, appropriate measures including initial responses such as activation of water sprinkler and smoke discharge system, notification to fire defense agency and traffic police, assistance in the evacuation of road users in a tunnel, provision of information on the situation to road users outside a tunnel and measures to prohibit vehicles from entering a tunnel are taken at this tunnel control center.

Information on operating conditions of road facilities inside and outside of a tunnel shall also be collected online at the tunnel control center for the real-time monitoring of these facilities and, when a breakdown or abnormal operation of a facility is detected, the condition of a facility concerned will be verified at the tunnel control center and appropriate measures including the dispatch of maintenance team shall be taken by the tunnel control center.


Collection of road, traffic and weather information
Roadside facilities
Rain gauge
Road patrol
Tunnel control center
Information processing and monitoring
- Various data processing devices and operator console
- Video wall (of images taken by CCTV cameras)
Control of the emergency facilities in tunnels
Ventilation system
Water sprinkler
Lighting system during power failure, UPS
Emergency facilities in a tunnel
CCTV
Emergency phone
Fire alarm
Fire detector
Provision of information to road users
Roadside equipment (VMSs)
Evacuation route
400m 150m

Source: JICA Expert Team

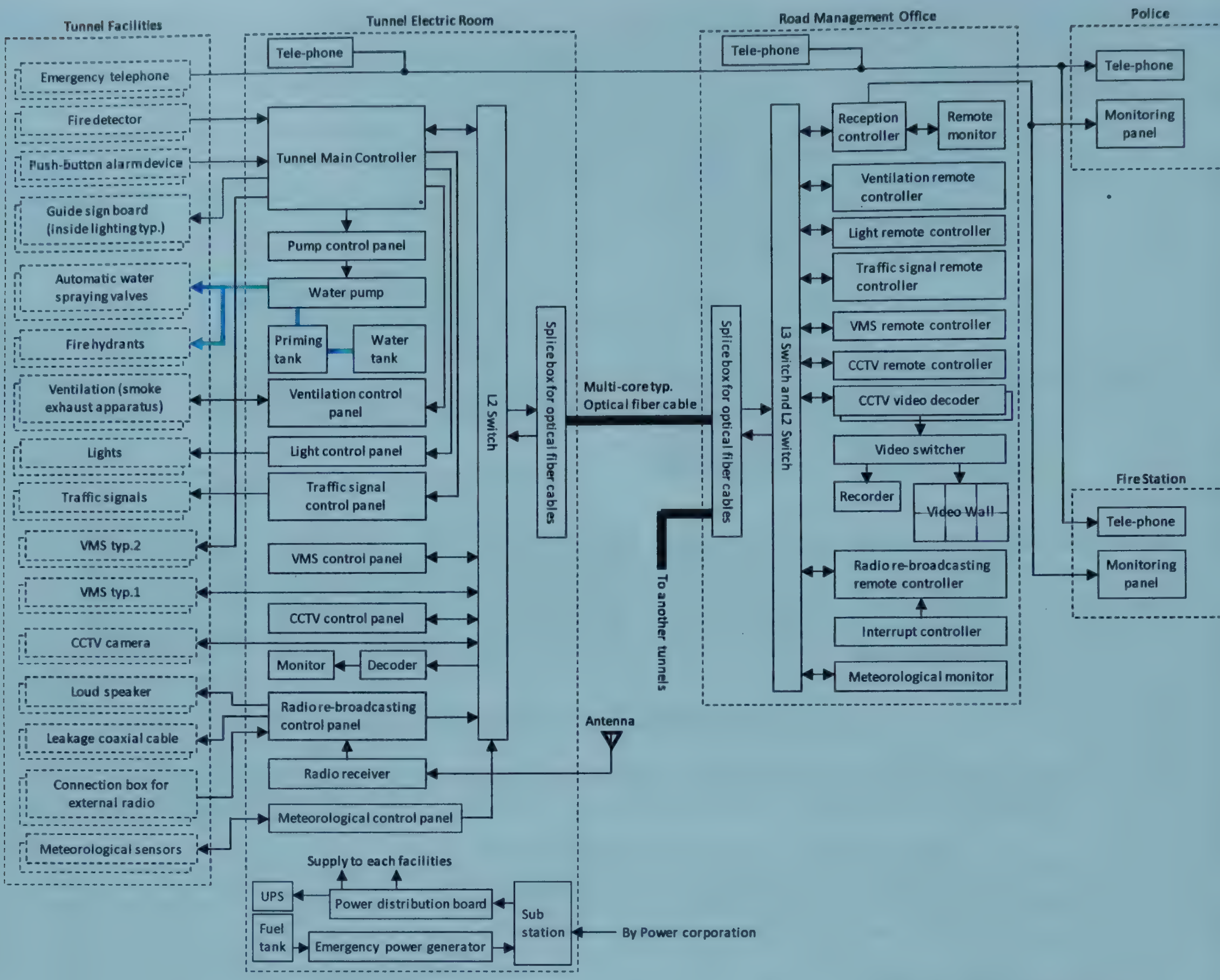
Figure 3-36: Outline of the Work at Tunnel Control Center

Moreover, the tunnel control center shall have the following functions.

- ✓ Collect data from terminal equipment
- ✓ Monitor and control terminal equipment
- ✓ Communicate with terminal equipment
- ✓ Manage databases
- ✓ Manage and control network
- ✓ Man-machine interface
- ✓ System clock
- ✓ Keep an operation log
- ✓ Prepare reports
- ✓ Connect emergency, mobile, and fixed-line telephones, etc.

3.7.4 System Composition for the Tunnel Control Center (recommended)

Figure 3-37 shows the recommended system composition for the tunnel control center for the operation of a tunnel. The system is designed to ensure uninterrupted traffic control in a tunnel with the installation of two remote monitoring and control systems and two remote monitoring and data processing systems configured in such a way that one is used as a primary system and the other as a backup system and that the backup system should automatically take over the function of the primary system when a problem, such as malfunction, develops in the primary system. The detail of the tunnel electric room is described in the chapter on tunnel facilities in “Guidelines for Tunnels”.


Tunnel Facilities
Emergency telephone
Fire detector
Push-button alarm device
Guide sign board (inside lighting typ.)
Automatic water spraying valves
Fire hydrants
Ventilation (smoke exhaust apparatus)
Lights
Traffic signals
VMS typ.2
VMS typ.1
CCTV camera
Loud speaker
Leakage coaxial cable
Connection box for external radio
Meteorological sensors
Tunnel Electric Room
Tele-phone
Tunnel Main Controller
Pump control panel
Water pump
Priming tank
Water tank
Ventilation control panel
Light control panel
Traffic signal control panel
VMS control panel
CCTV control panel
Monitor
Decoder
Radio re-broadcasting control panel
Radio receiver
Meteorological control panel
L2 Switch
Splice box for optical fiber cables
Supply to each facilities
UPS
Power distribution board
Fuel tank
Emergency power generator
Sub station
By Power corporation
Antenna
Multi-core typ. Optical fiber cable
To another tunnels
Road Management Office
Tele-phone
Splice box for optical fiber cables
L3 Switch and L2 Switch
Reception controller
Remote monitor
Ventilation remote controller
Light remote controller
Traffic signal remote controller
VMS remote controller
CCTV remote controller
CCTV video decoder
Video switcher
Recorder
Video Wall
Radio re-broadcasting remote controller
Interrupt controller
Meteorological monitor
Police
Tele-phone
Monitoring panel
Fire Station
Tele-phone
Monitoring panel

Source: JICA Expert Team

Figure 3-37: System Composition for the Tunnel Control Center

3.7.5 Works at Facility Control Center

The facility control center shall conduct monitoring and necessary control of operating conditions in tunnels. As well as maintaining normal function of the facilities and taking prompt measures in case of abnormal situations, it shall secure safety for road users when abnormal situations occur and prevent the expansion of damages. In addition, the facility control center requires to fully grasp the facility functions, operation characteristics, operation methods, and distribution systems, etc. With the effort in improving knowledge and technology, it shall conduct the operation rapidly and accurately while taking mutual cooperation with the traffic control center when abnormal situations occur in addition to day-to-day operations.

Facility control center shall monitor the operation activities below in normal situations:

- ✓ The monitor operation condition of the target facilities and control if needed
- ✓ Grasp condition of tunnel facilities as well as ventilation by monitoring CCTV cameras
- ✓ Grasp residual failure

- ✓ Grasp work description of periodic inspection, temporary inspection, repair, maintenance, and construction, and give necessary support and cooperation

Facility control center shall monitor the operation activities below in case of emergencies and/or malfunctions:

- ✓ Confirm automatic operation condition of relevant facilities based on abnormal malfunction and control if needed
- ✓ In cooperation with relevant agencies, conduct operation monitoring measures for recovery when abnormal malfunctions occur
- ✓ Inform and report to relevant authorities immediately

When fire accidents and/or other accidents occur inside a tunnel, the facility control center shall take close cooperation with the traffic control center and operate tunnel emergency facilities while providing necessary cooperation. When fire accidents and/or other accidents occur inside a tunnel, it shall inform and report to relevant authorities immediately.

In addition, the occurrence of fire in a tunnel shall be recognized by the following fire notifications.

- ✓ When CCTV cameras identify smoke, fire or abnormal vehicles, etc. that could possibly lead to fire after fire detector is operated (in a tunnel where CCTV cameras are installed)
- ✓ When fire detector is operated (inside a tunnel where CCTV cameras are NOT installed)
- ✓ When a push-button alarm goes off
- ✓ When a fire hydrant is used (with starting the pump)
- ✓ When the occurrence of fire is reported by emergency phone
- ✓ When CCTV cameras identify smoke or fire

In addition, the occurrence of an accident in a tunnel shall be recognized by the following notifications.

- ✓ When an accident etc. is reported by emergency phone, etc.
- ✓ When CCTV cameras in the grade “AA” tunnel identify an accident etc.

3.7.6 Operation of Emergency Facilities and Ganged Operation of Each Facility in Tunnel on Fire

When an occurrence of fire in a tunnel is recognized, a water sprinkler system is operated as follows:

- ✓ After the watering timer operates due to notification of a fire, the water sprinkler generally supplies water automatically in one-way traffic tunnel and two-way traffic tunnel respectively after a certain period of time following validation of tunnel emergency facilities, situation confirmation by using monitoring device and broadcasting evacuation guide.
- ✓ After the start of watering timer until the water supplying, however, operation shall be started as well as terminated decided overall by an operation leader in case of the following.

When an occurrence of fire in a tunnel is recognized, radio re-broadcasting (with interrupt function) in a tunnel or broadcasting item of loudspeaker generally performs as follows.

【When a fire occurs in a tunnel with water sprinkler】

- ✓ Broadcasting the occurrence of fire
- ✓ Broadcasting the evacuation guidance
- ✓ Notice broadcasting of water sprinkler

When a fire occurs in a tunnel, each facility (emergency, ventilation, TN lightening, CCTV, and radio re-broadcasting) shall perform the following fundamental ganged operation.

- ✓ Facilities for an emergency: Fire-extinguishing pump operates, which roles include fire spread prevention, initial firefighting activity on-site and support for firefighters, etc.
- ✓ Ventilation facilities: In the case of bi-directional tunnels, all ventilation facilities shall stop their operation to prevent the diffusion of smog. In the case of one-directional tunnels, a ventilation facility shall operate to control smog flow in traffic direction.
- ✓ Tunnel lightening: Tunnel lighting shall light up brighter than “daytime” mode. In the case of one-directional tunnels with two tubes, the same measure shall be performed in the other tube which does not suffer tunnel fire. in evacuation connection tunnel and escape tunnel, all lightings shall be turned on.
- ✓ VMS at tunnel portal: VMS at tunnel portal shall display a message to prevent road users from entering into the tunnel. In the case of a one-directional tunnel with two tubes, the same measures shall be performed in another tube which does not suffer tunnel fire. Moreover, in the case of a continuous multiple tunnel section, VMS operation shall be handled as if one single tunnel.
- ✓ VMS inside the tunnel: VMS inside tunnel ahead of fire accident, it does not link to fire operation. On the other hand, VMS before the fire accident shall display “STOP, Fire Ahead”.
- ✓ CCTV: When a fire occurs in a tunnel with a water sprinkler, interlock fixation shall be performed centering on the ignition point.
- ✓ Radio re-broadcasting and loudspeaker: When a fire occurred in a tunnel with a water sprinkler, automatic broadcasting becomes on-air.

3.7.7 Periodical Disaster Drill

For the higher safety of a long tunnel, it would be effective for a road operator to conduct disaster drills in collaboration with traffic police, fire fighting units, and towing companies. Disaster drill is typically performed inside a tunnel, with conducting road closure for a concerned section. In case conducing road closure is difficult for disaster drill, it can be done in other places such as parking at wayside amenities, interchanges, etc.

3.8 Tunnel Interior Works

3.8.1 Outline of Tunnel Interior Works

The side wall of a tunnel shall be furnished with interior facing in order to enhance traffic safety by improving the driving environment. Generally, there are two types of tunnel interior facing, one is "General interior facing" which can improve the visual environment of drivers inside a tunnel and another one is "Noise absorbing interior facing" which can reduce the level of noise around the tunnel portal. Since "Noise absorbing interior facing" is usually used for a special purpose and it is required environmental study for each tunnel individually to ensure noise reduction function of interior facing; therefore, this section shows the outline of planning, design, and material for "General interior facing" (hereinafter called "interior facing").

Nevertheless, this chapter only shows examples of design and material which is commonly used for tunnel interior facing, and does not aim to limit the method of design and material. Hence it is necessary to select a rational design method and reasonable material in terms of economic efficiency, durability, workability, traffic safety, etc. according to site condition.

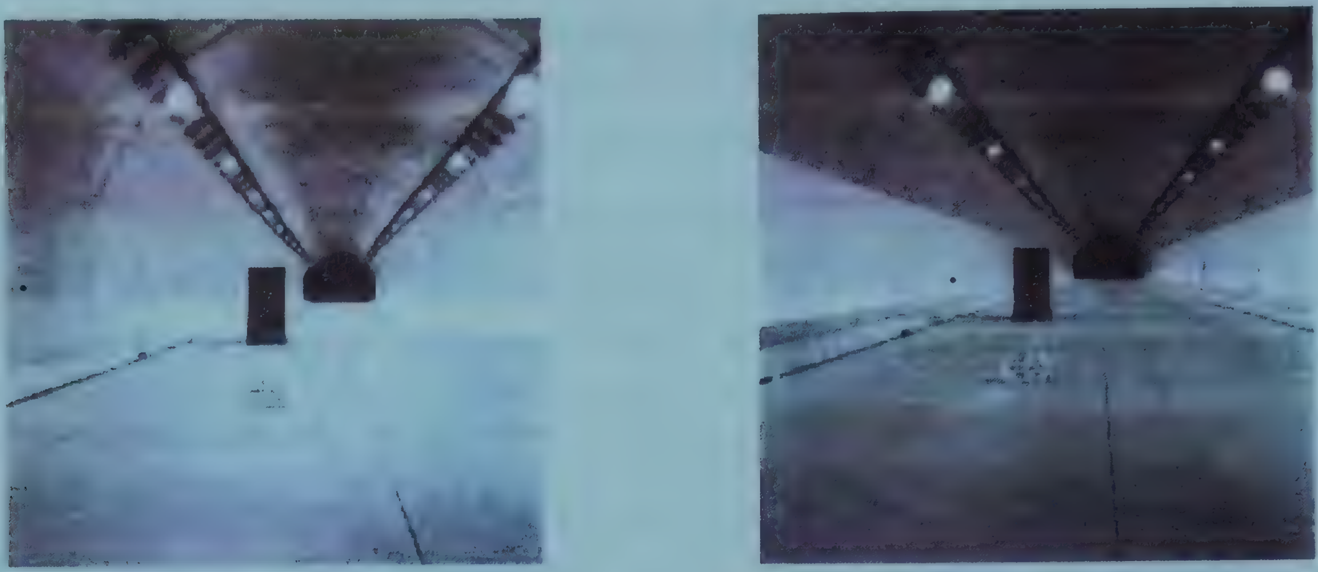
3.8.2 Roles and Purposes

Generally, the purposes of the interior facing of the tunnel are as follows;

- ✓ Improve visibility of drivers and keep a good visual environment by working as the background of vehicles ahead and obstacle
- ✓ Not let drivers feel uncomfortable by maintaining an aesthetic view inside the tunnel
- ✓ Improve traffic safety by making drivers recognize the location of side walls of a tunnel easily as well as improving the visual guidance effect
- ✓ Improve the lighting effect inside the tunnel

It is necessary to make a good visual environment for drivers inside tunnels to enhance traffic safety and comfortable because the driving environment and space inside tunnels are different from bridges and open embankment/cut sections. From this point of view, it is considered that keeping side walls of tunnels with high luminance and aesthetic appearance as well as improving a visual environment inside tunnels can contribute to give better visibility of vehicles ahead, to find obstacles earlier, and to pursuit more stable, and finally can be leading to safer driving and comfort. Especially interior facing of tunnels on highways shall be highly functional and effective because vehicles run usually faster on highways than on ordinary roads.

In addition, vehicles ahead are often recognized by the contrast of luminance between them and side walls of tunnels (of course it depends on the distance between vehicles as well as effects on visibility), so the bigger contrast of luminance is, the better visibility is as shown in Figure 3-38. Therefore it is necessary to make drivers gain better visibility by proper cleaning of the surface of interior facing to recover luminance, and by giving bigger contrast with side walls and vehicles even vehicles with low luminance.



It is difficult to recognize vehicles ahead and/or obstacles due to the small contrast of luminance between them and side walls of a tunnel if interior facing is not furnished and side walls are dark

Vehicles ahead and obstacles can be recognized easily and properly due to high luminance background, better visual environment, bigger contrast of luminance between them and sidewalls, and easier recognition of the location of side walls by furnishing interior facing and bright side walls

[9]

Figure 3-38: Contrast of Visibility inside a Tunnel with/without Interior Facing

3.8.3 Conditions

It is needed to determine specifications of interior facing works of tunnels in consideration of conditions in tunnels and efficiency of O/M works to fulfill the purposes presented in Section 3.8.2 ('Roles and Purposes'). Therefore interior facing works of tunnels shall be fulfilled following terms and conditions described below:

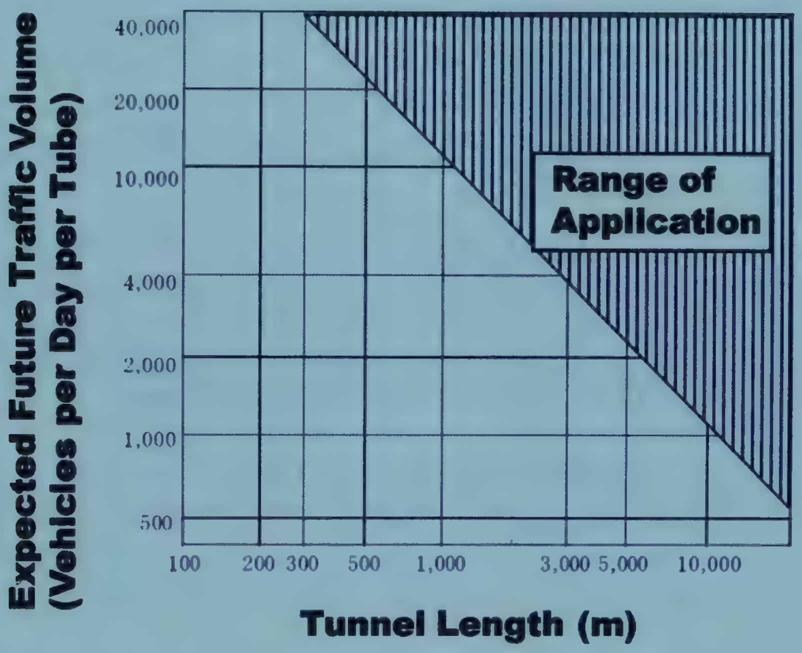
- ✓ The interior facing shall keep the shape which can use effectively a limited inner space of a tunnel, and it is favorable to use the material for the interior facing which fits curved side walls of a tunnel to cover well because there is only a narrow space left between side walls of a tunnel and the horizontal clearance.
- ✓ The surface of interior facing shall be of bright color with a high ratio of surface reflection, and hard to be stained easily by soot and smoke by gas emissions for example, in order to gain the good lighting effect as well as the big contrast of luminance by interior facing works. And the high ratio of surface reflection is maintained on a long-term basis and recovered easily by cleaning as well.
- ✓ The interior facing of a tunnel shall have a good appearance and its structure shall have enough strength against various external factors, such as wind pressure caused by vehicles running at high speed, cleaning pressure by a cleaning vehicle, snow removal pressure around tunnel portals, etc.
- ✓ Materials of the interior facing which has enough freezing and thawing resistance, are durable in cold areas and resistant to snow, ice, and freezing in the winter season shall be used.
- ✓ Materials of the interior facing shall be fire resistant and uninflammable, and they shall not generate toxic gases in case of fire accident in a tunnel.
- ✓ Construction works of the interior facing shall be economical, and maintenance works such as repair, replacement, etc. shall be effective as much as possible.
- ✓ Materials of the interior facing shall have little risk to cause a second disaster when the vehicle(s) collide(s) with the interior facing, which would cause a chain

of breaking and scattering of broken pieces. Also, materials and methods to attach the interior facing to the side walls of a tunnel shall be durable on a long-term basis and not let the interior facing materials fall due to aging deterioration.

3.8.4 Installation Criterion of Interior Facing

It is desirable that interior facing is provided in all of the tunnels from the viewpoint of its functions. However, a criterion of whether interior facing should be provided or not has been stipulated in consideration of investment effects from the economical viewpoint and tunnel conditions, especially focusing on the traffic volume and the tunnel length which are the major factors to control driving conditions in a tunnel.

Interior facing shall be basically installed to tunnels in the range of application as described in Figure 3-39.



[9]

Figure 3-39: Range of Application of Interior Facing Works

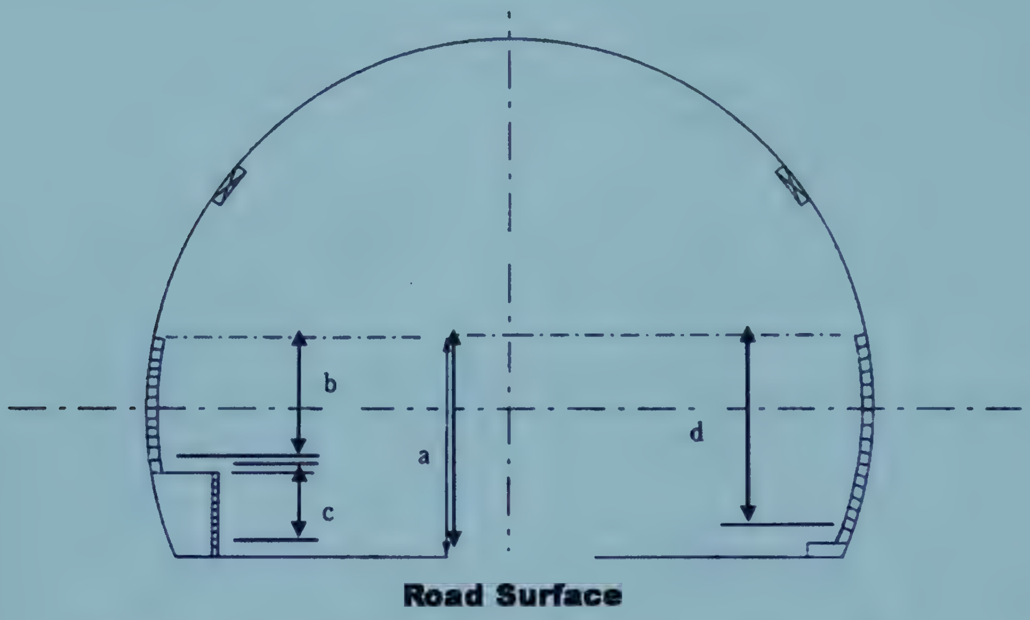
Interior facing can be installed even if a tunnel is out of the range mentioned above if judged to highly need it from the engineering point of view, such as 1) a tunnel located on continuous tunnels section, 2) a tunnel has not preferable geometric condition (e.g. vertical slope with over 3.0%, horizontal curves with less than 500m, 3) a tunnel which is expected to have a large number of large-sized vehicles, etc.

3.8.5 Height of Interior Facing Works

It is necessary for drivers to collect appropriate information on the geometric aspect of a tunnel and traffic conditions in order for them to drive in a tunnel safely and smoothly. Drivers make decisions based on such information and operations of their vehicle suitable for their driving environment. Especially, it is said most of the necessary information, or 80% or more of it are gained by eyesight, even drivers can collect information from five senses such as eyesight, hearing, and smell, etc. That is the reason why we shall provide a good visual environment by lighting and interior facing in a tunnel, where visual information can be gained correctly.

Usually, the viewpoint of the driver(s) for a passenger car is at 1.2m-height, and the one for a large vehicle, generally about 2.5m-height. Drivers confirm their safety of driving by seeing vehicles ahead, obstacles on the road, lane markings, and signs, etc. It means that the line of sight of the driver on a passenger car and/or a large vehicle tends to move and stay between the height of 1.2m and/or 2.5m which parallel to the road and downwards. Therefore it is effective to furnish interior facing on the side walls within this area for guiding the line of sight of the driver(s). Also, evaluations of a visual environment don't have a big difference by the difference of the heights of interior facing, white lighting used recently is good at color rendering, provides clear sight of a whole space in tunnels, and has effects to improve a visual environment.

Figure 3-40 shows a height to furnish interior facing.



a: The height of Interior Facing (H=2.5m),

b: The height of Interior Facing on the left side of the side wall,

c: The height of Interior Facing on inspection Foot Pass, d: The height of Interior Facing on the right side of the side wall

[9]

Figure 3-40: Height of Interior Facing in a Tunnel

When the height of the refurbished interior surface is lower than the existing one, the points to be paid attention to are as follow:

- ✓ It shall be made sure that required luminance on the road surface is maintained, as the lighting effect becomes lowered.
- ✓ In case sodium light is used in a tunnel, the lighting in the tunnel shall be switched to white color lighting. The timing to switch lightings and the schedule of interior-facing works shall be well coordinated in advance.
- ✓ At a location where water leakage from a construction joint, etc. presents, appropriate measures shall be performed so that the effects of interior facing shall be demonstrated.

3.8.6 Materials

As materials for interior facing are placed under severe conditions in a tunnel, it is highly necessary to choose materials which have certain performance. Table 3-10 shows the examples of the materials which have been typically used for interior facing.

Materials shall be selected in consideration of various conditions such as tunnel length, traffic volume, large-sized vehicle ratio, gradient, ventilation method, condition of water leakage, method, and frequency of cleaning, etc. as well as economic efficiency, traffic safety, durability, the efficiency of maintenance works comprehensively. It shall be also paid attention carefully that interior facing works need to be conducted in a tunnel, i.e. restricted space.

Table 3-10: Materials to be Considered for Interior Facing of Tunnels

A) Tile	E) Aluminum Board
B) Glass-Fiber Reinforced Cement	F) Tile Panel
C) Enamel Board	G) Ceramic based Large Board
D) Stainless Steel Board	H) Others

[9]

Considering severe conditions after installation, highly durable materials are required. It is also necessary to select materials in consideration of economic efficiency including the efficiency of maintenance works of interior facing such as replacement of damaged parts after traffic in service. This is because interior facing has a high risk to be damaged by accidents. In this sense, it is desirable that materials for interior facing shall be easy to procure and maintain as well as marketable.

Glass-fiber reinforced cement board was used the most commonly in the past; however, there are some cases it should be replaced just in a dozen years because it is hard to be cleansed after traffic in service, its edge tends to crack due to the pressure of a washing brush, and its metal fittings (attachments) and frames tends to be corroded.

As for panels of interior facing, since the panels have risks to disturb smooth traffic flow by falling down on traffic lane due to corrosion of metal fittings (attachments) and frames, double safety measures shall be considered to prevent panels from being fallen down along with ordinary safety measures such as regular inspection and maintenance.

A review of tiles by surveys, researches, and experiences in the past has revealed the following facts:

1) Tiles placed directly on side walls of tunnels are enough functional even after over 30 years passed
2) Tiles have long-term cleaning recovery property
3) Tiles are not frequently replaced for maintenance
4) Tiles are easy to wash. Especially, currently, the direct tiling method (tiles are directly pasted on side walls of a tunnel) is considered the most economical method for the interior facing of tunnels.

However, in case a lot of water leaks on the surface of the lining and the treatment of water leakage needs to be required, or in case pollution of interior facing such as efflorescence is forecasted due to a lot of water leakage, the direct tiling method is unfavorable.

Also, if interior facing is newly installed on the side walls of existing tunnels, it is necessary to select appropriate material and construction method of interior facing in consideration of existing wiring and piping arrangement of tunnel emergency facilities, etc.

(1) Materials for Direct Tiling

Specifications for materials of interior facing by direct tiling are shown below.

Tile

Ceramic type tile, which is marketable and commonly used for exterior facing of buildings, can be used for interior facing by direct tiling. However, it is required to be the white color with high reflection processing by glazing. This reflection ratio of tiles also needs to be recovered easily after cleaning. It is also required that it shall be low water absorption type (preferably less than 3%) in order to avoid freezing damages.

The preferable size of tiles is approx. 100mm (width) * 50mm (height) in consideration of cost, workability, marketability and beauty appearance, etc. The thickness of the interior facing (tiles with an adhesive agent) is preferably less than 30mm but shall be decided in consideration of the distance between side walls and horizontal clearance.

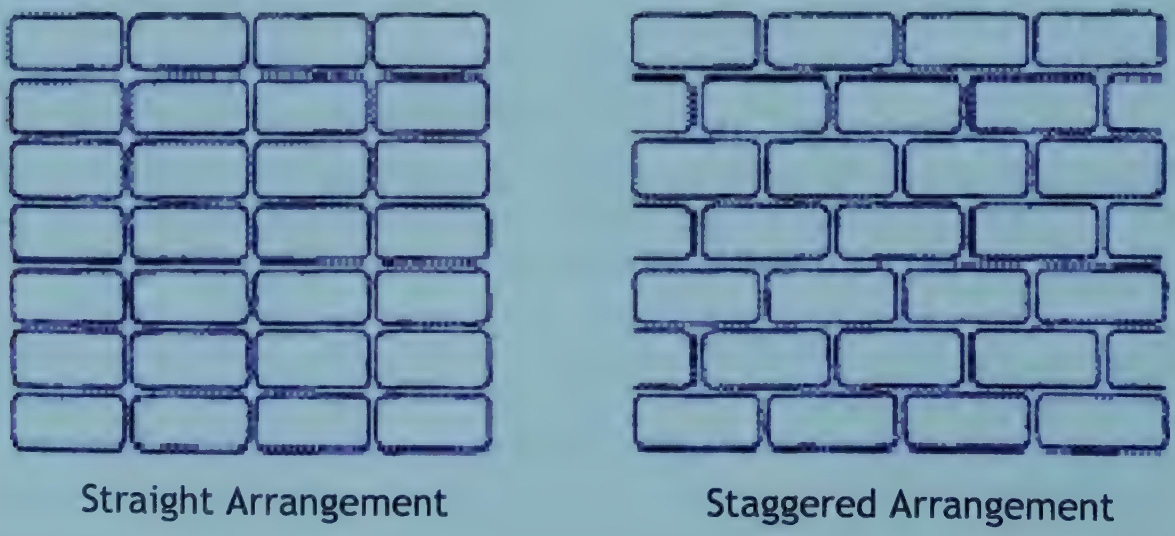
Adhesive Agent

Pretreatment of tunnel walls shall be necessary, for example, cleaning, sanding, and drying up the surface of lining concrete and/or primer treatment. Adhesive agent shall have enough strength which tiles shall not be peeled and fallen down easily by wind pressure, cleaning work. An epoxy type of adhesive agent is recommended. Preferably, trial loading is conducted to attached tiles before the opening of a tunnel to confirm the strength of the adhesive agent.

Joint

Joint, which is the gap between tiles, shall be required to fix tiles and to avoid water penetration behind tiles. However, it shall be minimized, preferably approx. 5mm, because joints reduce the reflection ratio of interior facing since they are not reflective and difficult to clean once they get dirty.

And the straight arrangement of tiles is more preferable to staggered arrangement in consideration of workability, easiness of maintenance (cleaning), easiness of arrangement at construction joint of tunnel lining, etc.


Straight Arrangement
Staggered Arrangement

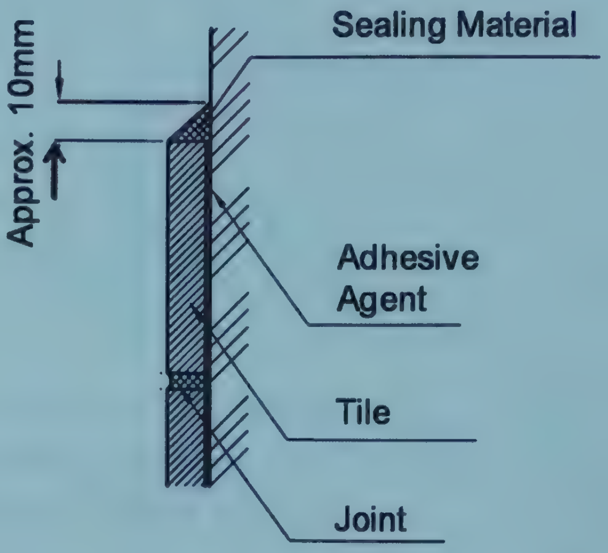
[9]

Figure 3-41: Types of Joint Arrangement

Sealing

Sealing shall be conducted on top and both sides of interior facing by direct tiling to avoid water penetration to adhesive agent part, i.e. between tiles and the side walls of a tunnel by water seepage from the concrete joint, dew, cleaning, etc.

An example of sealing is shown in Figure 3-42. Sealing material shall be selected in consideration of its functionality, workability, durability, etc.



[9]

Figure 3-42: Sealing of Interior Facing

(2) Materials for Paneling

Specifications for materials of interior facing by paneling are shown ~~in~~ below.

Panel

Fiber reinforced cement board, Metal board, or Tile panel are commonly used for interior facing of tunnels by direct / raised paneling. Material of panels shall be selected with comprehensive consideration, such as strength and thickness against external forces, weight, durability, water absorption ratio (deformation & deterioration by water, freezing damage), and effectiveness of maintenance (easiness of replacement, etc.).

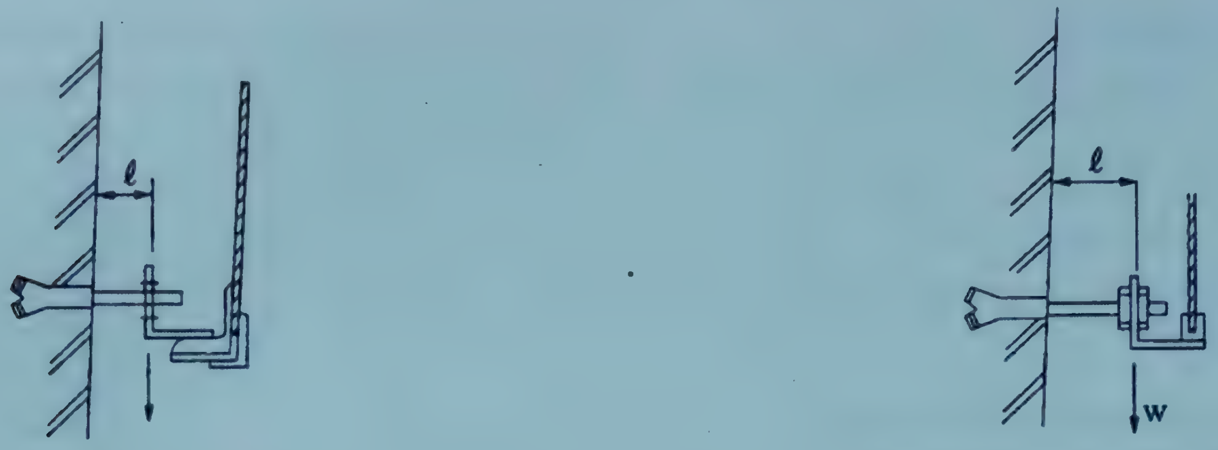
Panels shall be white color or painted by high durability white color paint, and with a high reflection by glazing or coating. This reflection ratio of panels also needs to be recovered easily after cleaning. In the case of tile panel, specifications for materials of interior facing by direct tiling as shown in 3.8.6 (1) shall be referred. Panels shall also be non-flammable and less generated smoke and toxic gases by fire in order not to expand the fire accident in a tunnel.

Panels for interior facing are preferably coated by organic type paints such as fluorine resin coating etc., or inorganic type paints such as silica type coating, etc. Coating type shall be selected in consideration of dirty-resistant, recovery of reflation after cleaning, surface hardness, durability, etc., and inorganic type paints are generally more preferable than organic type ones.

In the case of raised paneling, panels are placed by metal fittings at a distance less than 100mm from the side walls of a tunnel. It is also required to provide joints (discontinuous parts) at concrete joints of tunnel lining.

Metal Fittings (Attachments)

Examples of fittings of interior facing by raised paneling are shown in Figure 3-43. Stainless type of metal fittings shall be used for fittings of raised paneling in consideration of severe and poor conditions for corrosion inside a tunnel. Anchor bolts shall be selected to have enough strength to support panels.



Metal Frame Method

Point Support Method

[9]

Figure 3-43: Examples of Fittings of Interior Facing by Raised Paneling

3.8.7 Construction Method

Table 3-11 shows typical construction methods for the interior facing of tunnels.

Table 3-11: Typical Construction Methods and Materials of Interior Facing

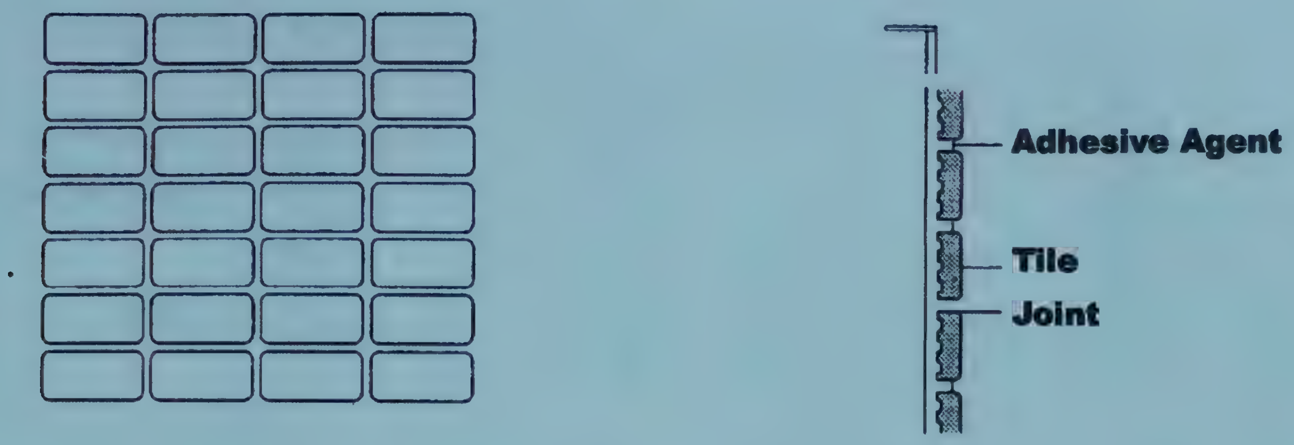
Construction Method	Fixing Method	Material	Fixing Location
Direct Tiling	- Adhesive agent	Tile	- Side wall on inspection foot pass - Side walls of a tunnel
Direct Paneling	- Adhesive agent and Anchor bolt - Metal fittings and Anchor bolts	Fiber reinforce cement board	- Side wall on inspection foot pass - Side walls of a tunnel
		Metal board	
		Tile panel	
		Others	
Raised Paneling	- Metal Frames - Point support	Fiber reinforce cement board	- Side walls of a tunnel
		Metal board	
		Tile panel	
		Others	

[9]

(1) Direct Tiling

Figure 3-44 shows the example of the direct tiling method. “Direct Tiling” means to attach tiles on the side walls on a tunnel and/or inspection foot pass by applying adhesive agent, and pressing tiles on the walls with vibrators for example. Here, basically, tiles shall be attached to the walls by an adhesive agent.

Pretreatment of the walls shall be necessary to make sure that panels are kept adhesive in a good condition for a long time. I.e., the sanding treatment to make the wall surface smooth and to remove stains, dust and concrete form oil enough. Due condensation on the adhesive surface may be assumed depending on weather conditions. Hence in such a case, tiles shall be attached after dew on the adhesive surface is removed well by wiping with a cloth or drying with a fan.


Adhesive Agent
Tile
Joint

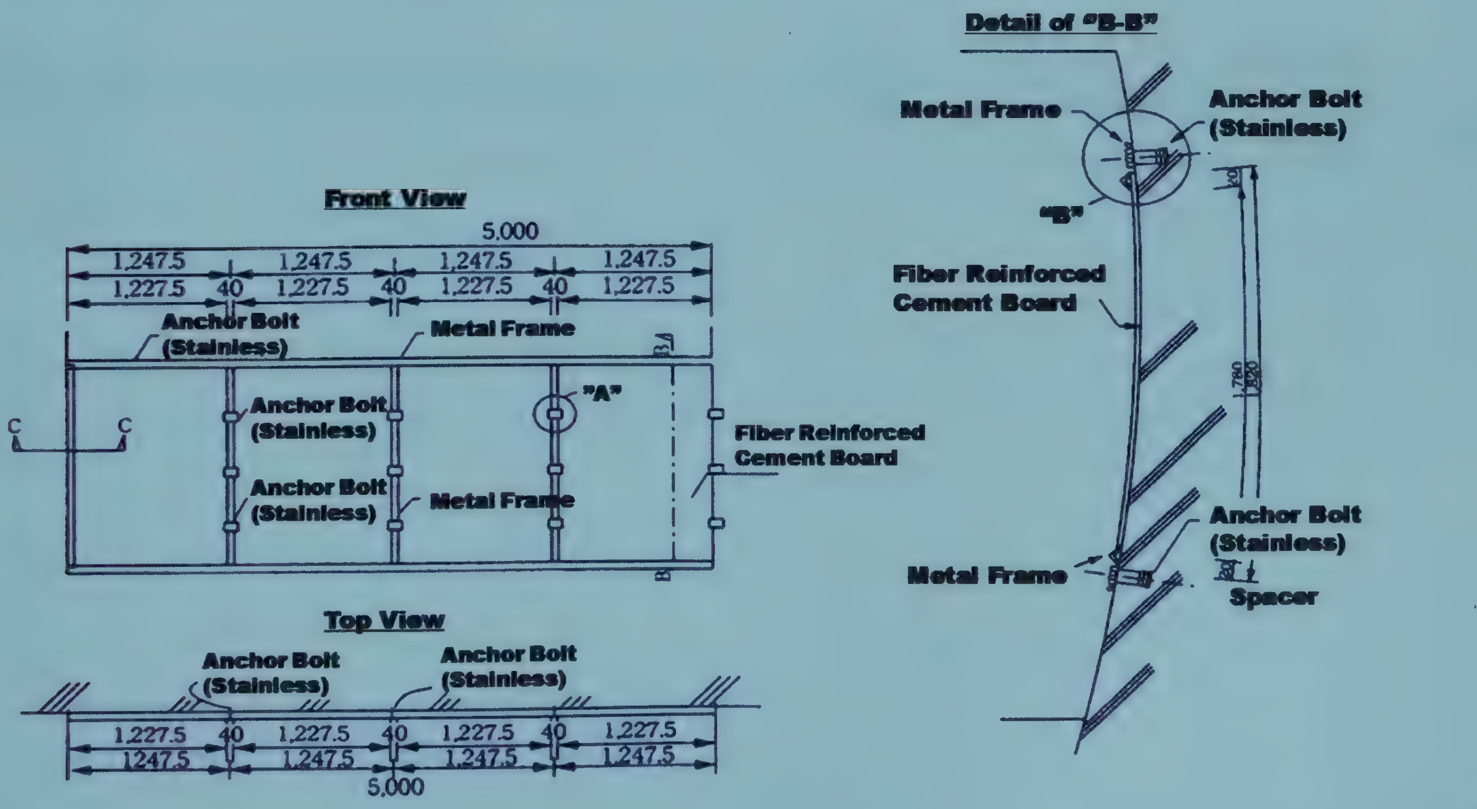
[9]

Figure 3-44: Example of Direct Tiling Method

(2) Direct Paneling

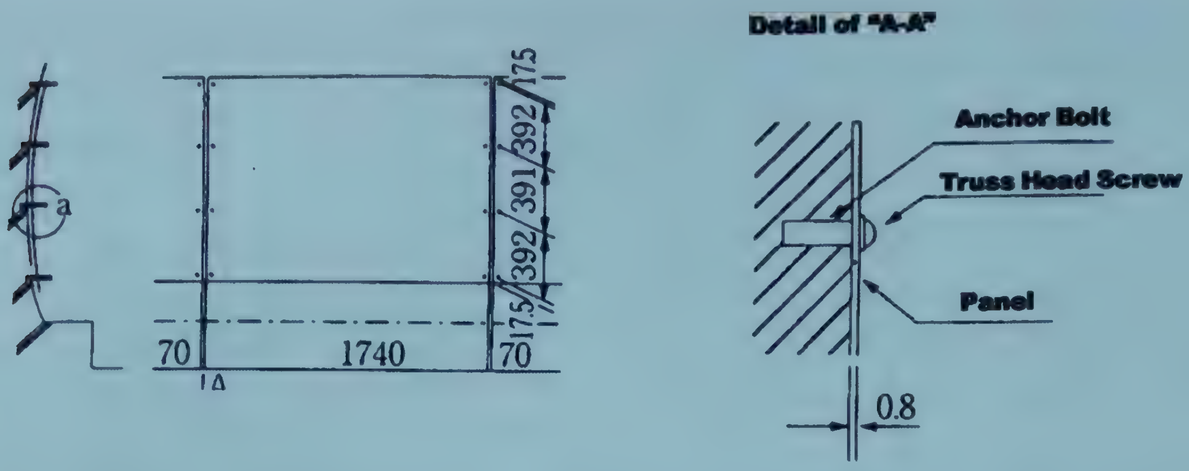
As described in Figure 3-45 and Figure 3-46 below, the "Direct Paneling" method means that panels are directly attached on the side walls of a tunnel and/or inspection foot pass by anchor bolts, mounting metal fittings, or adhesive agent. This method can be a more durable and more economical option than the "Raised Paneling" method because this method can reduce the number of metal fittings compared with "Raised Paneling", and share cleaning load with concrete lining on the back side. Hence, panels can be made thinner as well.

As for maintenance, it has the advantage that a crash between a wall and a vehicle will not cause major damage to panels. However, if a panel is placed over a construction joint of lining concrete, it cannot respond to a displacement of the joint and it will be damaged. Therefore, it is suggested that panels should not be attached over a joint.


Front View
5,000
1,247.5
1,247.5
1,247.5
1,247.5
1,227.5
40
1,227.5
40
1,227.5
40
1,227.5
Anchor Bolt (Stainless)
Metal Frame
Anchor Bolt (Stainless)
"A"
Anchor Bolt (Stainless)
Metal Frame
C
C
B
B
Fiber Reinforced Cement Board
Top View
Anchor Bolt (Stainless)
Anchor Bolt (Stainless)
1,227.5
40
1,227.5
40
1,227.5
40
1,227.5
1247.5
1,247.5
1,247.5
1,247.5
5,000
Detail of "B-B"
Metal Frame
Anchor Bolt (Stainless)
"B"
Fiber Reinforced Cement Board
Anchor Bolt (Stainless)
Metal Frame
Spacer

[9]

Figure 3-45: Example of Direct Paneling (Fiber Reinforced Cement Board)



[9]

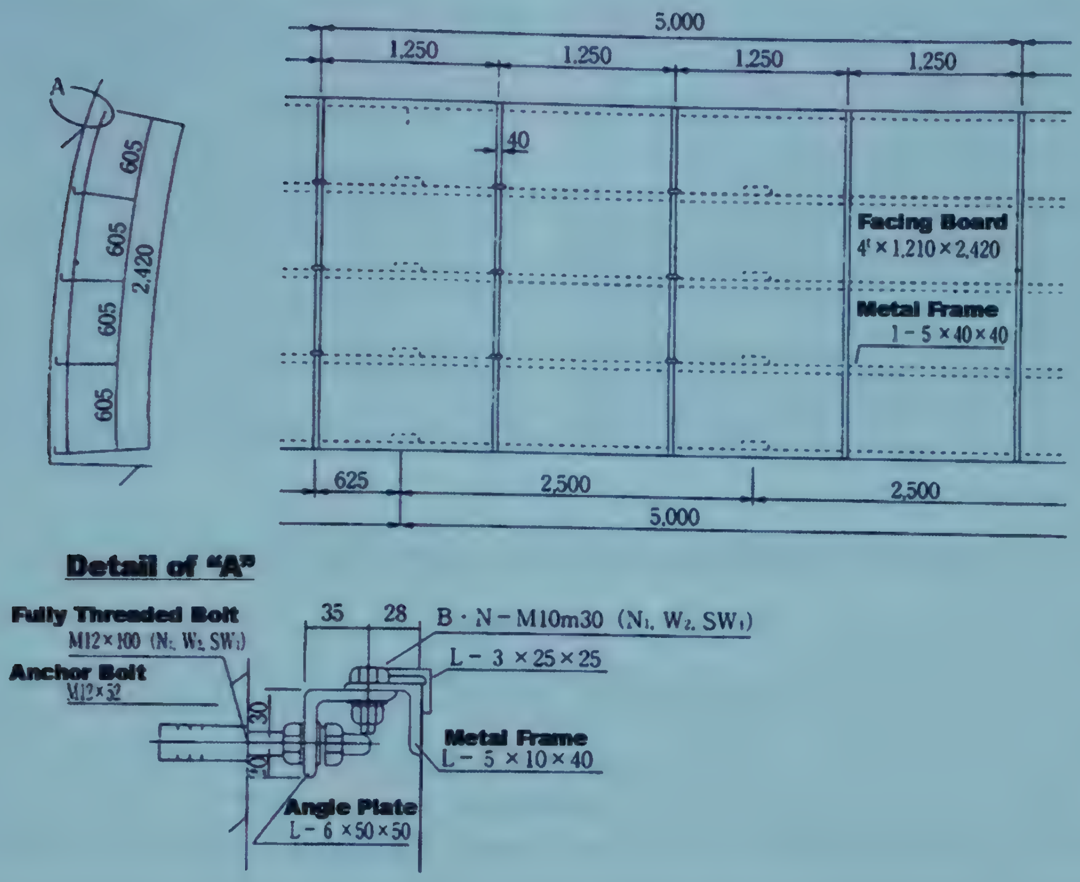
Figure 3-46: Example of Direct Paneling (Enamel Board)

(3) Raised Paneling

The "Raised Paneling" method was a common and conventional construction method of interior facing of tunnels. As described in Figure 3-47, a gap between the side wall and the panel shall be less than 10cm, and a panel is 1) to set on horizontal metal frames inserted between upper and lower brackets (Metal Frame Method), or 2) only to put between the brackets without metal frames (Point Support Method).

The Point Support Method is a more economical and easier construction method than the Metal Frame Method, however, there are some problems for the Point Support Method, such as panels are vibrated by resonance when large vehicles pass, or cleaning makes cracks at the edge of supporting points. Therefore, the Point Support Method can be applied just to tunnels with a short length, low traffic volume, cleaned with wet brushes (less cleaning pressure), and/or cleaned not frequently.

If panels are set over a construction joint of lining concrete, the fitting method which can respond to a displacement of construction joint shall be also applied for interior facing.


5,000
1,250
1,250
1,250
1,250
A
605
605
605
605
2,420
40
Facing Board
4' × 1,210 × 2,420
Metal Frame
1 - 5 × 40 × 40
625
2,500
2,500
5,000
Detail of "A"
Fully Threaded Bolt
M12 × 100 (N₂, W₂, SW₁)
Anchor Bolt
M12 × 52
35
28
30
B · N - M10m30 (N₁, W₂, SW₁)
L - 3 × 25 × 25
Metal Frame
L - 5 × 10 × 40
Angle Plate
L - 6 × 50 × 50

[9]

Figure 3-47: Example of Raised Paneling (Fiber Reinforced Cement Board)

(4) Others

One of the other construction methods is to use tile panels as forms for the concrete casting of the side wall of the inspection foot pass, although it is required to examine carefully the workability of this method.

Today, new products and various construction methods are being developed. In this regard, it is worthy to consider using such new technology in consideration of their workability, efficiency of maintenance and cleaning, durability, safety for road users, economic efficiency, etc.

CHAPTER 4 SAFETY MEASURES ON HILL ROADS

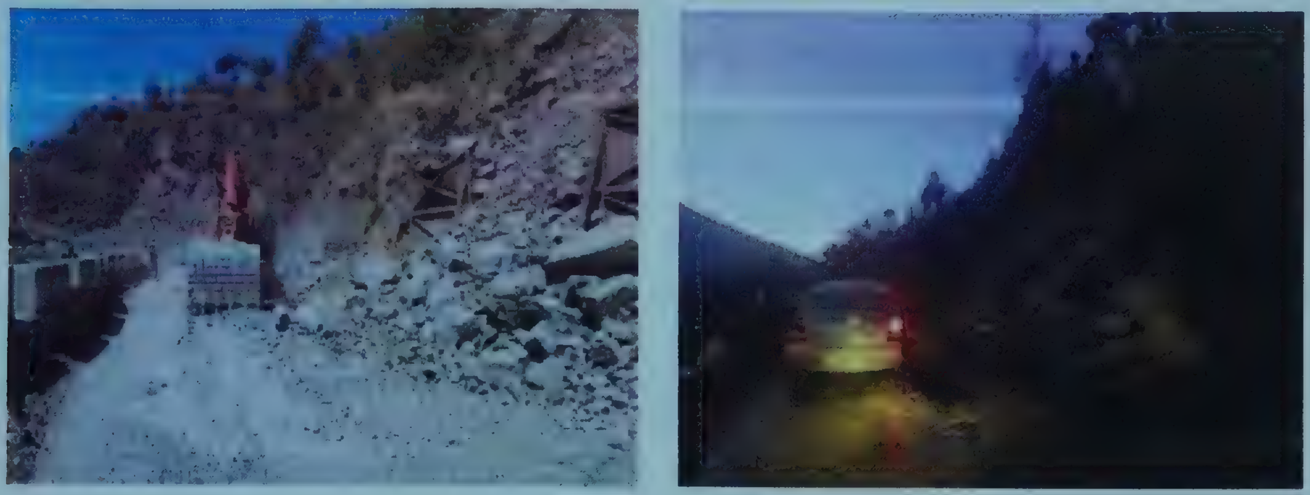
4.1 Outline of Road Safety on Hill Roads

Road safety is one of the common social issues in the world. WHO research in 2009 reports approximately 1.2 million fatalities of road accidents in the whole world. According to MoRTH, the year 2018 saw 151 thousand traffic fatalities in India, which is one of the worst in the world. It is to be kept in mind that the problem of traffic accidents is not unassailable. Many countries have tried various approaches to reduce traffic accidents. Since there are many possible causes of traffic accidents, effective methods of solving road safety issues should be taken by such as disseminating traffic information, improving black-spots, conducting a road safety audit and proper maintenance works.

The work zones, on the other hand, are usually very crowded areas not only with regular traffic but also with construction traffic such as workers, machinery, and vehicles. The main contributors to accidents around the work zone are as follows: lack of attention, speeding, failure to yield the right-of-way, tailgating (lack of a safe distance), severe weather, improper safety measures in work zones, etc. An ideal approach to reduce accidents is to ensure a working area that does not influence the regular traffic flow by segregating and shielding the site. Even nowadays in India, road users often run into work zones that are not segregated and shielded, as shown in Figure 4-1. In case sufficient lighting devices are not installed, it poses a critical threat to road users.

Work Zone Traffic Management Plans (WTMPs) are required in this regard to meet the safety needs of regular traffic as well as construction traffic, ensuring minimum disruption for the pedestrians who move and access the properties. The primary purpose of the WTMPs is to provide a reasonably safe and efficient movement for road users through or around the work zones while protecting the workers and equipment. It is equally essential to ensure the safety of workers in work zones, who perform varied tasks within the limited workspace. One set of WTMPs cannot guarantee safety in all conditions of a work zone, and defining all possible applications also may not be practically possible. Therefore, typical applications shall refer to "Guidelines on Traffic Management in Work Zones (IRC:SP:55)" with the depiction of the usual deployment of devices. The contents of this Guideline are basically according to those in the IRC Guideline. The site based on the specific WTMPs should be meticulously prepared and implemented with the concurrence of the road authority. In particular, it is vital for mountain regions to prepare the WTMPs of safety assurance since there is only limited space with slopes adjacent to roadways.

This chapter describes good practices of various road safety measures in Japan.



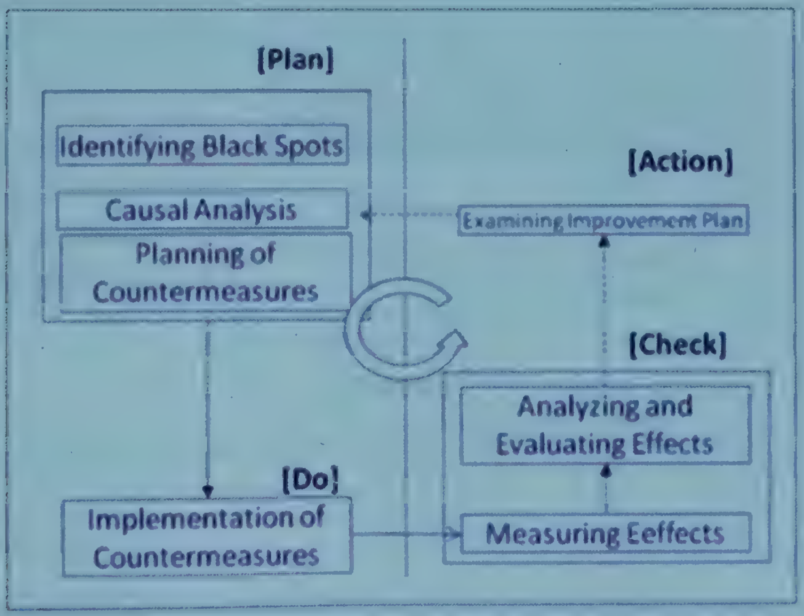
Source: JICA Expert Team

Figure 4-1: Examples of Work Zone on Hill Roads (Left: Daytime, Right: Night time)

4.2 PDCA Cycle on Road Safety Measures

Road safety measures are recommended to be implemented based on traffic and accident statistics. The effectiveness of safety measures is assessed by comparing the number of accidents or the change of driver's behavior before and after the respective measure. When measures are not sufficient, additional or modified measures will be conducted based on scientific data. This approach is so-called PDCA cycle, which represents the initial letter of "Plan", "Do", "Check", and "Action, and is very important for strategic road safety management.

PLAN: Planning and designing road safety measures
DO: Implementation of measures
CHECK: Analyzing and evaluating the effects
ACTION: Examining the improvement plan


[Plan]
Identifying Black Spots
Causal Analysis
Planning of Countermeasures
[Action]
Examining Improvement Plan
[Check]
Analyzing and Evaluating Effects
Measuring Eeffects
[Do]
Implementation of Countermeasures

Source: JICA Expert Team

Figure 4-2: PDCA Cycle of Road Safety Management

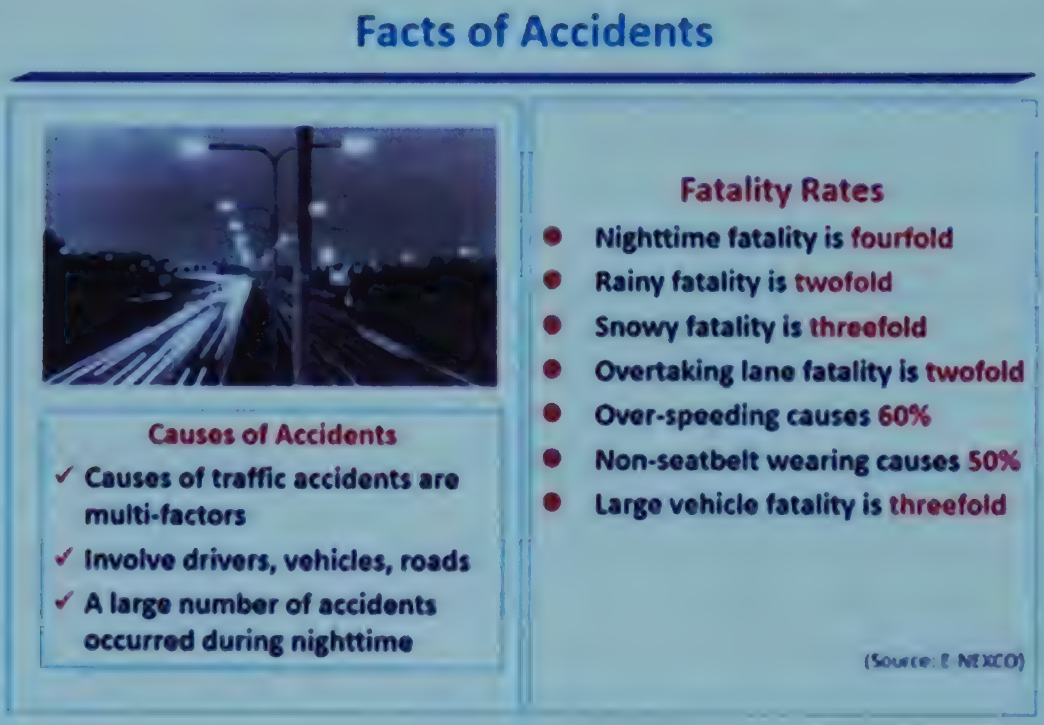
Besides, engineers should consider drastic/long-term viewpoint (e.g. flyover) and immediate/short-term viewpoint (e.g. traffic signs or roadside furniture) in the process of PDCA cycle.

4.3 Approaches to Improve Road Safety

Causes of traffic accidents would be multi-factors and at random. They may involve drivers, vehicles, and/or the road environment. Drivers may mishandle the steering wheel, may mix up brakes and accelerator pedals, and may doze off behind the wheel. Vehicles may have mechanical troubles such as a puncture, flat tires gear malfunction, or short-circuit in the electrical wiring. Roads may have damage and destructions such as potholes or slope landslides, or some other types of problems such as severe weather or fallen objects on the carriageway.

However, some tendencies have been observed in the data accumulated from the Japanese expressway network over the past decades, which have proven that a large number of traffic accidents have occurred during nighttime. The nighttime fatality rate is fourfold as much as that of the daytime. Rainy fatality is twofold, and snowy fatality is threefold. Vehicle operation may cause an accident because the overtaking lane fatality is twofold, overspeeding fatality is 60% of the total accidents, 50% of the total accidents did not wear a seatbelt, and large vehicle fatality is threefold as much as that of passenger cars. Therefore, the following sections describe road safety countermeasures focusing on

- ✓ Safety measures for night driving
- ✓ Safety measures for severe weather driving
- ✓ Safety measures for accident-prone points
- ✓ Road Safety Audit/Inspection



Facts of Accidents

Causes of Accidents

- ✓ Causes of traffic accidents are multi-factors
- ✓ Involve drivers, vehicles, roads
- ✓ A large number of accidents occurred during nighttime

Fatality Rates

- ● Nighttime fatality is fourfold
- ● Rainy fatality is twofold
- ● Snowy fatality is threefold
- ● Overtaking lane fatality is twofold
- ● Over-speeding causes 60%
- ● Non-seatbelt wearing causes 50%
- ● Large vehicle fatality is threefold

(Source: E-NEXCO)

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Figure 4-3: Approaches to Improve Road Safety

4.4 Typical Road Safety Measures

4.4.1 Safety Measures for Night Driving

1) High Visibility Road Marking

Road marking can play a key role in reducing accidents and facilitating smooth traffic flow. It is difficult to visualize highways without their markings. Road marking has three main functions: 1) to guide traffic, 2) to define the territorial limit of each road user, and 3) to warn of approaching obstacles, hazards like diverging noses.

Applying high visibility road marking with sound and vibration function for the edge line of the carriageway is very effective not only for enabling drivers to see the lane markings clearly at night but also for giving drivers a warning when they inattentively deviate from the carriageway.

The sound and vibration marking shown in the following figure uses special thermoplastic material. It does not lose its visibility because of the protruding shape from the road surface, even during wet nighttime. With its rumble shapes, when it runs over by a vehicle, they produce sensory and auditory impulses to the driver. In Japan, high visibility road marking with sound and vibration has been proved to reduce 40% of the number of traffic accidents at the site.

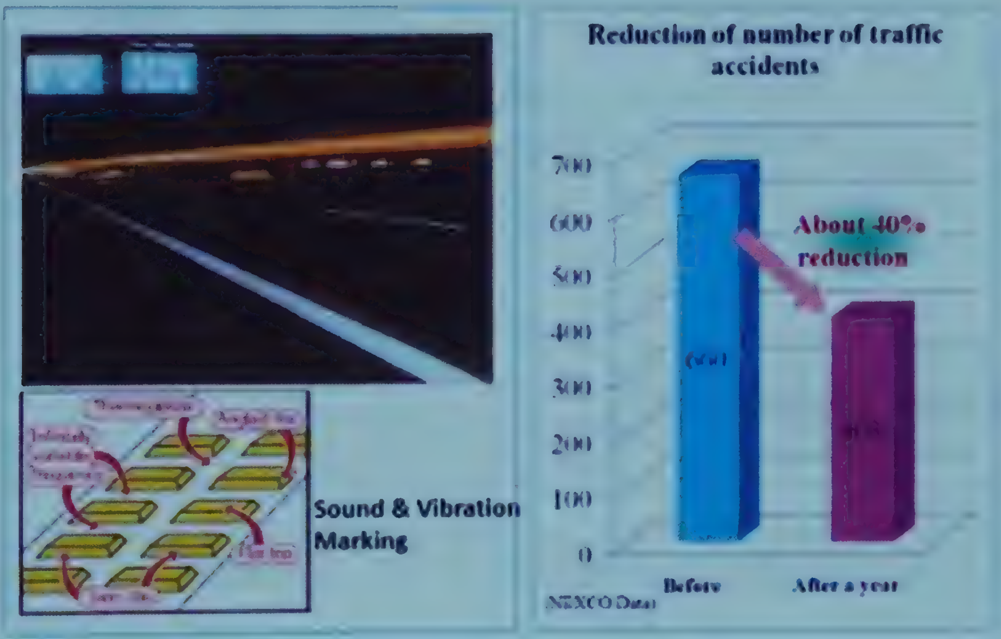

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Figure 4-4: High Visibility Road Marking

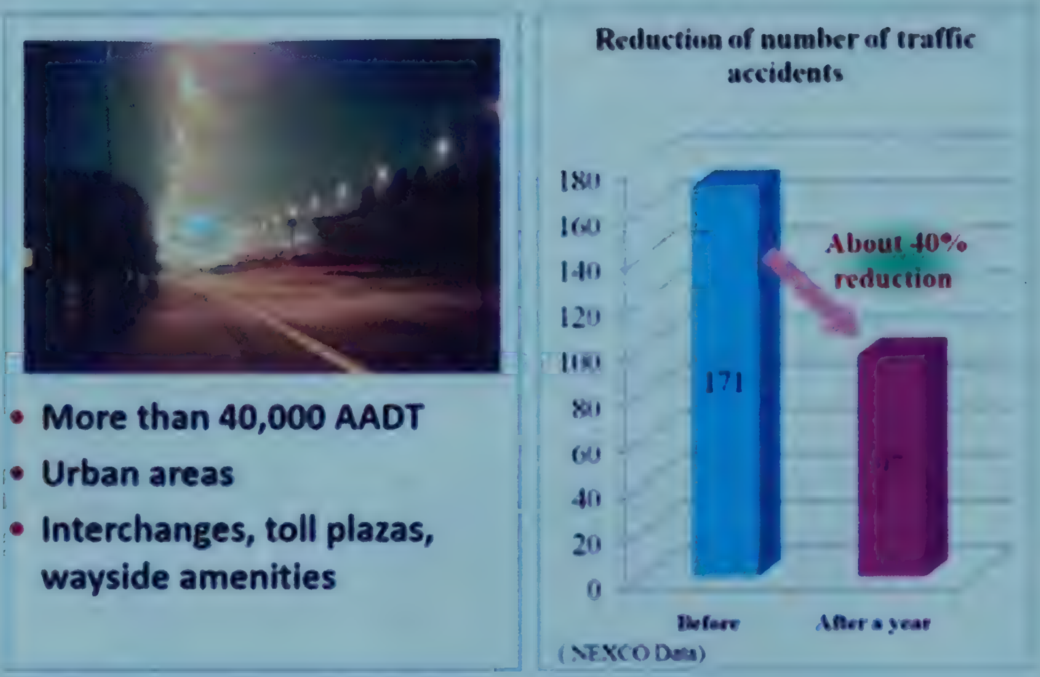
2) Lighting Installation

The main objective of lighting is to illuminate the carriageway, fallen objects within RoW, and the environment, especially during foggy and rainy weather as well as at night. The lighting is warranted to provide adequate visibility to motorists during the day in severe weather and night for defining road geometry, fallen objects, and the road environment.

Lighting is of great significance at potential accident sites such as intersections junctions, toll plazas, and wayside amenities. In Japan, a reduction of traffic accidents at night by 40 % was observed by lighting installations at an accident-prone point on expressways.

However, the lighting requires a permanent and sometimes necessarily costly budget. Necessary cabling along highways and the regular provision of power supply should be taken into account when choosing where to install lighting devices. The Guidelines for Expressway recommends warrants for expressway lighting in Indian situations as follows;

- ✓ Where expressway section with AADT of 40,000 or more is located near cities.
- ✓ Where three or more interchanges are located with an average spacing of 2.5 km or less
- ✓ Where expressway passes through urban or suburban areas for a length of 3 km



- More than 40,000 AADT
- Urban areas
- Interchanges, toll plazas, wayside amenities

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Figure 4-5: Lighting Installation

3) Self-luminous Delineator

Delineators are erected along the roadsides and indicate road alignment. It functions mainly at night to guide drivers. The delineators are effective in promoting safe driving by providing advanced information on the alignment, which serves to prevent traffic accidents.

For accident-prone sections, self-luminous delineators have been proven effective to reduce the number of traffic accidents. The self-luminous delineators, which consist of an internal light source and a controller to flash automatically, are installed mainly in road sections where accidents are frequent and at locations where visibility is particularly poor because of mist, fog, snow, etc.

The power source for the self-luminous delineator is either by electricity line or a solar battery. In Japan, the effect of self-luminous delineators at the place where there used to be many traffic accidents at night has shown the reduction of the number of accidents by 20 %.

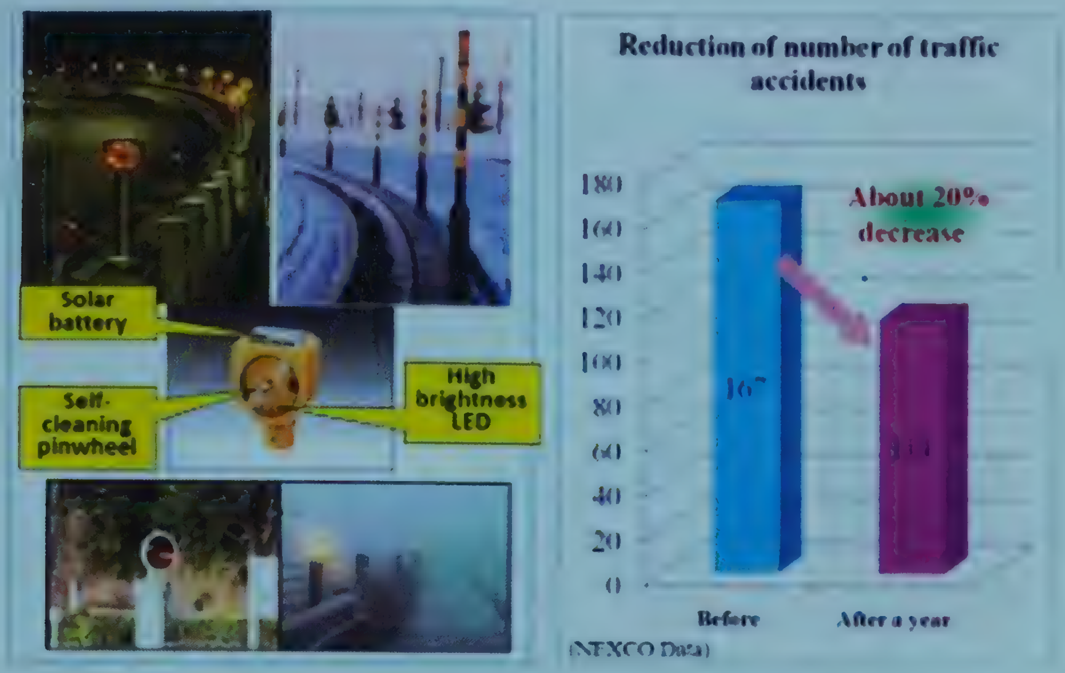

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Figure 4-6: Self-luminous Delineator

4) Anti-glare Device

An anti-glare device is installed for reducing the headlight glare of opposing traffic at night, which may distract the driver from driving tasks. This contributes to reducing the number of traffic accidents. In Japan, the effect of the installation of anti-glare devices has been observed as a 20 % reduction. The commonly used materials are net types and board types.

Installation of the anti-glare device depends on many factors such as accident experience, high night-time traffic volumes, or severe highway geometry. For sections of crest or curves with the horizontal curvature radius is smaller than 750 m, it is desirable to install them.

Anti-glare devices are generally installed on the median strips. Desirable spacing is 4 m and the height is set at 1.4 m considering the height of headlight of passenger cars and large-sized vehicles running in the opposite directions.

Installation of anti-glare devices can be omitted in the sections with the following characteristics;

- ✓ The median strip has a width of 7 m or wider
- ✓ The difference in the elevation of the centerline in opposing directions is 2 m or greater
- ✓ Lighting facilities are installed continuously

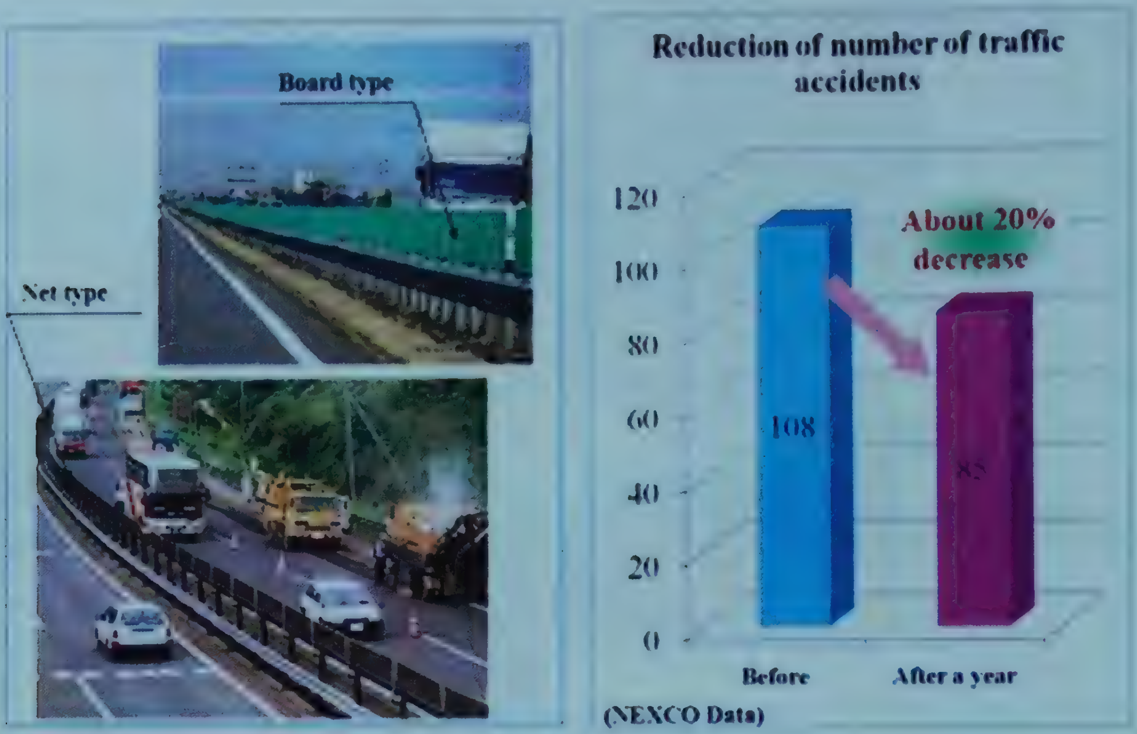

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Figure 4-7: Anti-glare Device

5) Curve Indicators

The following figure (left top) shows some examples of curve indicators during the night at East Coast Road in Tamil Nadu. Lateral delineator posts are made of plastic retro-reflectors so as to be highly visible both by day and by night. Placed next to the carriageway, many of them are knocked down or missing probably because of some vandalism or something. It is frequent that retro-reflectors are stolen anywhere in the world.

Chevron-type panels delineate curves quite clearly. Being properly placed, they ensure visual guidance to traffic. Road work signing and delineation regularly use such safety devices as well. Using high-performance retro-reflective materials no longer requires frequent maintenance. However, they are often in places where they are easily knocked down in the event of a vehicle leaving the curve.

Retro-reflective road studs are used in addition to road markings where circumstances demand, both as center line and as edge delineation of carriageways and roads. Also, for instance, they are very useful for improving the wet performance of road markings. However, they are rarely used for expressways because their shapes protrude from the road surface and may cause an impact on vehicles running at a high speed.

Products of solar-powered type are available for all kinds of curve indicators. When the road condition is especially severe due to a sharp curve or frequent fog, for example, self-luminous types show high performance during the night and severe weather like rain and fog. On expressway in Japan, the application of curve indicators showed a reduction of 60% of accidents, most of the reduction observed at night.

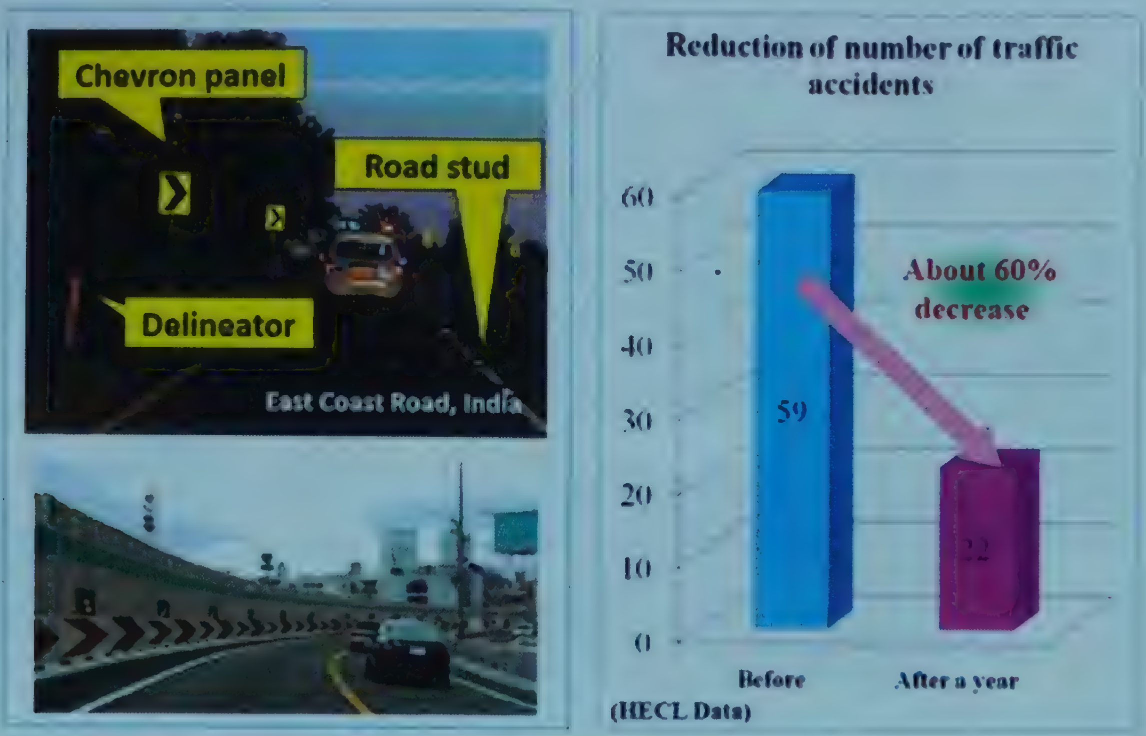

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Figure 4-8: Curva Indicators

4.4.2 Safety Measures for Severe Weather Driving

1) Porous Asphalt Pavement

Water on the surface of the carriageway not only reduces skid resistance between tires and pavement surface but also produces hydroplaning. On rainy days, traffic accident often occurs on dense asphalt pavement.

Porous asphalt pavement can keep skid resistance high even on rainy days. This type of pavement has a high performance of water drainage function. It is important for road safety to improve surface drainage during rain at places where water puddles on the road surface. Such places as sag sections in vertical grades, sections where the cross grade changes from one side to the other tend to have poor drainage function.

Porous asphalt pavement eliminates water puddles and wet road surfaces, which often produce water splashing or mist behind vehicles. This improves visibility a great deal. In addition, the occurrence of hydroplaning phenomenon becomes rare. It is observed in Japan that the application of porous asphalt pavement reduced the number of traffic accidents by 80% in the places where there used to be many accidents on rainy days.

Porous asphalt pavement has other important benefits in addition to water discharge. The voids inside the porous pavement absorb the traffic noise and reduce the noise level as much as three to four dB, which is equivalent to half the amount of the energy of sound.

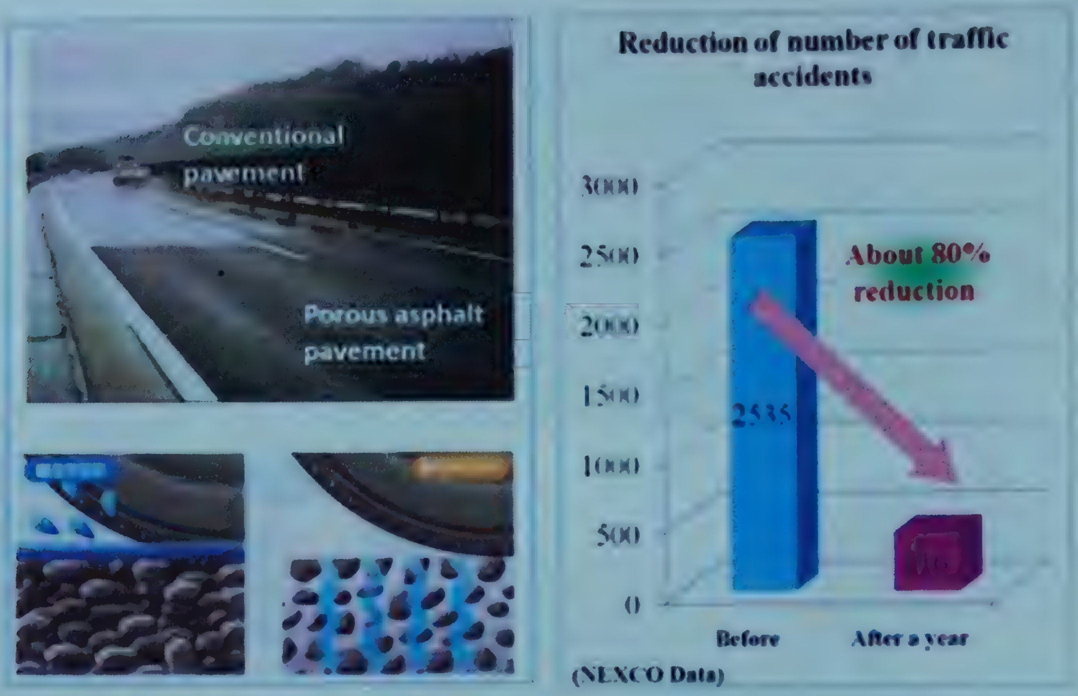

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Figure 4-9: Porous Asphalt Pavement

2) Combinational Measures

Visibility is very important for high-speed driving. Visibility in severe weather such as fog, rain, snow, and dust storm is a great hazard to road safety. These weathers are, however, seldom last long hours and disappear as time elapses. In many countries, people could not help but accept these severe weathers.

However, it is vital for expressways and highways because of high speed. In the case of 100km/h, a vehicle goes to approximately 30m a second. It is enough distance to cause a large accident. And also multiple collision often occurs on expressway and highway in severe weather. In the cases, expressways and highways have to be closed for a long time period because of the cleanup of traffic accidents

In order to avoid the above, self-luminous delineators, halogen delineators, high visibility road markings, externally illuminated road signs, self-luminous chevron panels; are now commonly used to improve visibility during severe weather.

Actually, the number of hours in severe weather is very small. However, it is desirable to adopt a measure, which has a small initial cost rather than a high operational cost.

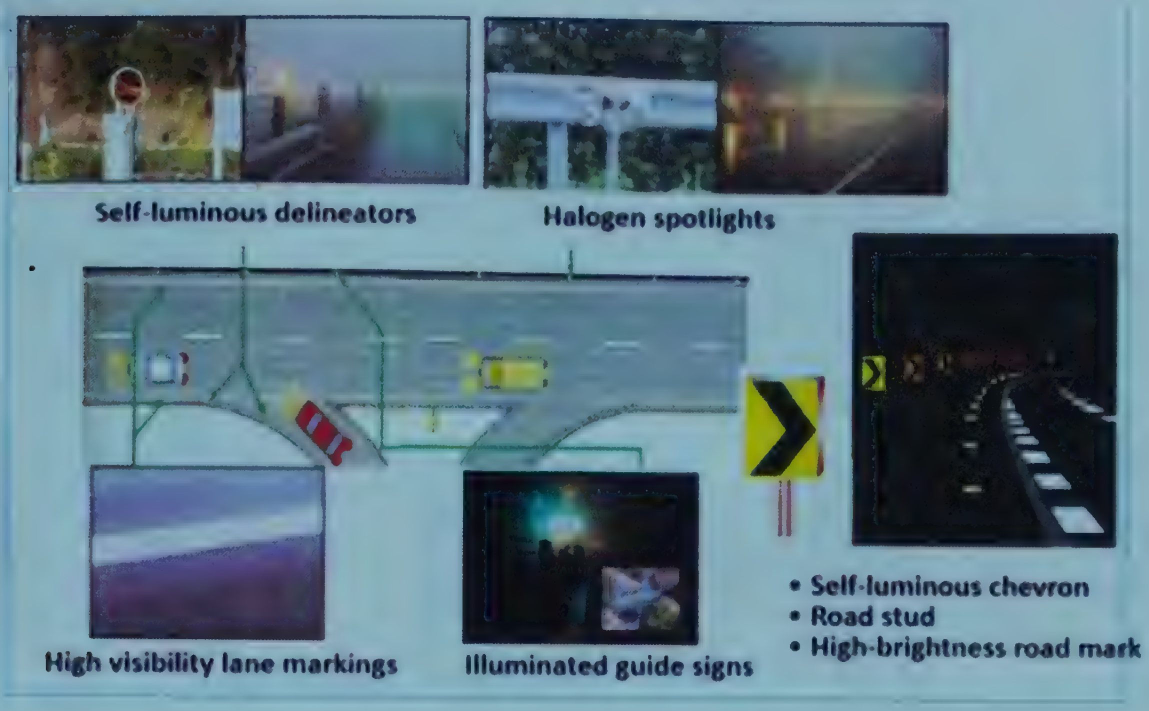
Self-luminous delineators
Halogen spotlights
High visibility lane markings
Illuminated guide signs
• Self-luminous chevron
• Road stud
• High-brightness road mark

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Figure 4-10: Combinational Measures

4.4.3 Safety Measures for Accident-prone Points

1) Rumble Stripe using Thin-layer Surface Pavement

This is one of the applications of thin-layer surface pavement. Rumble strips or speed breakers, which lower traffic speed forcibly by their high vertical stand, are common in India (needless to describe it). This section shows rumple stripe using the thin-layer surface pavement.

The thin-layer surface pavement is pavement laid on the surface of existing pavement with a thickness of about 2 to 3 cm. It is mainly used for preventive maintenance. A maximum aggregate grain size of 5 to 15 mm is usually used. Because of its feature of thin layer, it uses a smaller amount of material and lowers the cost, and shortens the work period. Types frequently used recently are crushed stone mastic pavement in order to improve rigidness and water-tightness, and drainage pavement in order to improve skid resistance and noise reduction.

In some countries, the thin-layer surface pavement is used in order to improve the skid resistance for the sections of sharp curves, where frequent accidents occurred. Later it has turned out that the thin-layer surface pavement is very effective to reduce traffic accidents because of its features to produce sound and vibration when a vehicle runs on it. It has a great effect to alert inattentive drivers and slowing down overspeeding vehicles.

As materials, epoxy resin for binder and hard aggregate, as shape; a width of 0.5-1m, the thickness of 2.5 -1.5 cm installed on the pavement at intervals of 5-30m, are commonly practiced in Japan. Japan observed a reduction of accidents by 60 %.

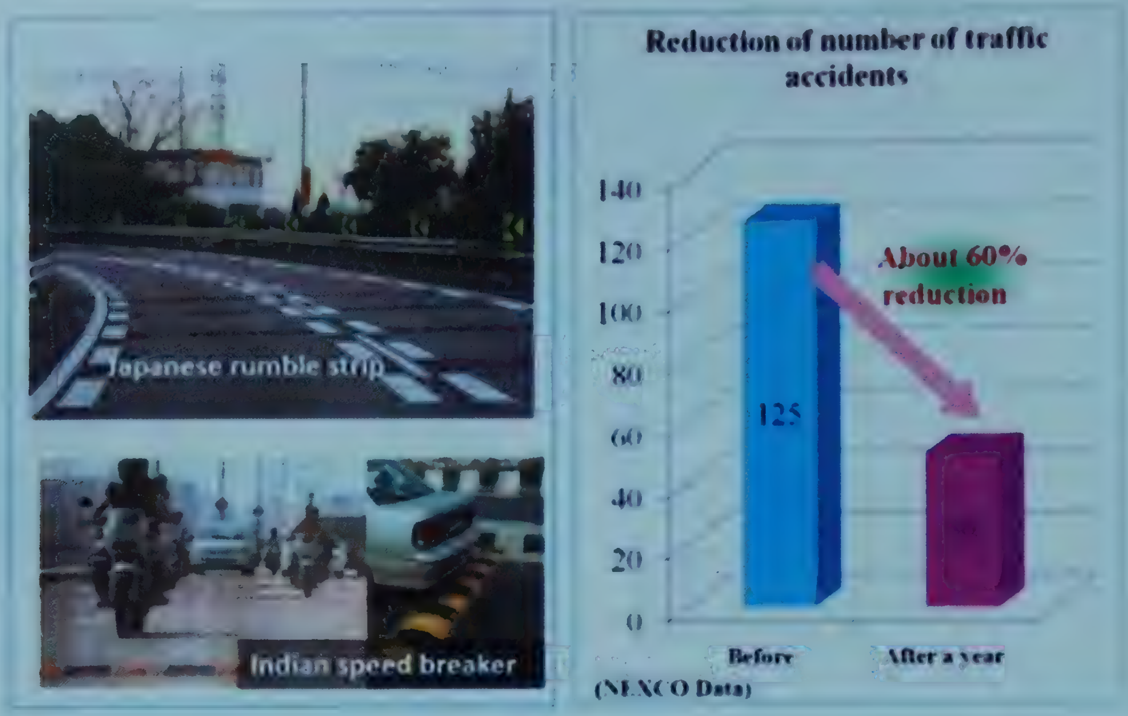

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Figure 4-11: Rumble Stripe using Thin-layer Surface Pavement

2) Reinforced-type Median Guard Rail

When a car loses its control and veers onto the median across to the opposing lane, most probably it becomes a very serious accident involving many oncoming vehicles. From many experiences of tragic accidents, a new type of median guard rail was invented. This type is double-sided with long arms on both sides. When a vehicle hits this guard rail, the posts may deflect but the arm supports by resting on the ground. In so doing the other side beam is kept the high preventing vehicle from jumping over it.

This kind of accident became more frequent as the size of the vehicle became larger and the speed faster. The total length of the arms was designed as 1.0 m and the intervals of posts as 2.0 m. The material for the beam was also strengthened.

By replacing the old type with the new type, a reduction of traffic accidents by 40% has been observed

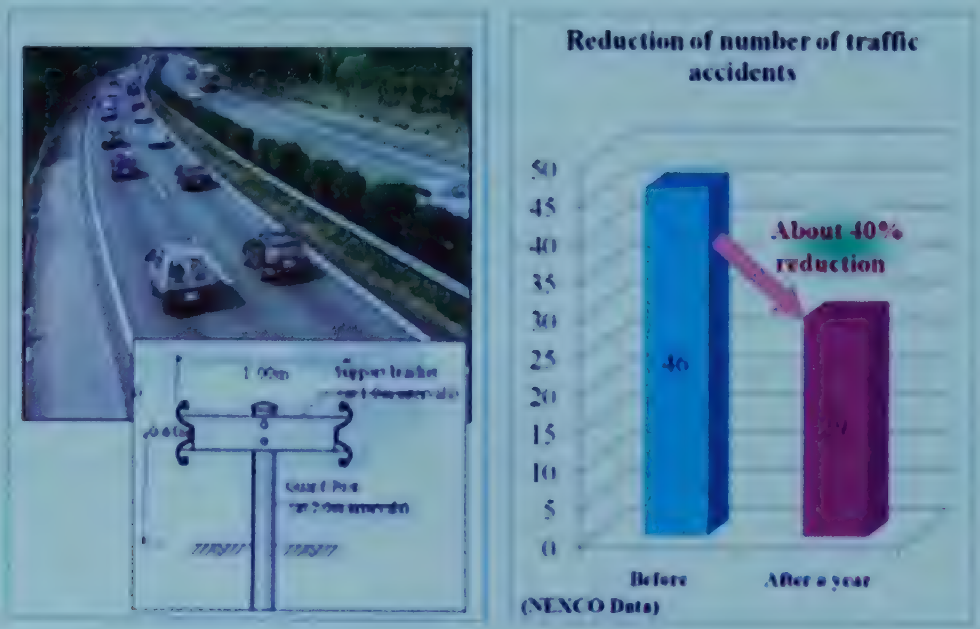

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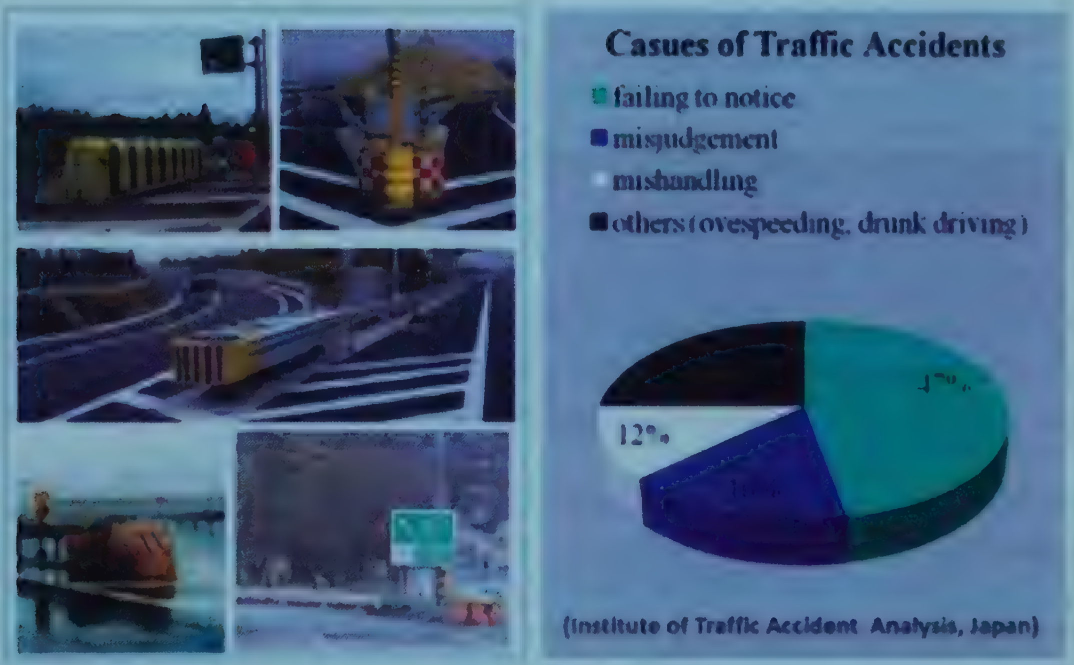
Figure 4-12: Reinforced-type Median Guard Rail

3) Diverging Nose Indicator

The largest number of causes of traffic accidents is that a driver failed to notice an imminent danger, accounting for 47% of the total causes of traffic accidents. The next largest is misunderstanding or misjudgment of the situation of impending danger to make a judgment to avoid the danger (16%). The third is that even though a driver noticed an imminent danger and made a correct decision to avoid it but failed to handle it (12%).

This data indicates that if a driver is appropriately informed of impending danger to notice it and understand the meaning of the danger, 63% of the accidents could be avoided. Blinkers at a nose of a diverging point make a driver notice that the vehicle is approaching a point to make an action. Still then 12% of drivers mishandle the situation and a collision impact absorber is installed to save those. There are various types of collision impact absorbers in different shapes and using different materials.



(Institute of Traffic Accident Analysis, Japan)

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Figure 4-13: Diverging Nose Indicator

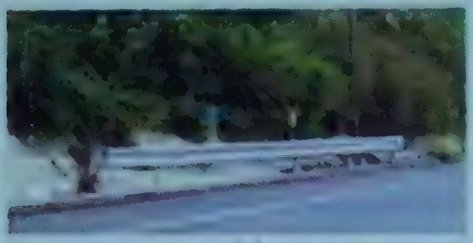
4) Safety Barrier Protection

The ideal roadway would be entirely free of any roadside obstructions or other hazardous conditions. This is rarely practical because of natural, economic, and environmental factors. A stretch of continuous safety barrier should be installed along the edge of a roadway, for the sections where a mishandled vehicle deviating from the roadway may encounter a serious hazard.

However, the main function of the safety barrier is to minimize the danger for both the driver and the party which may be affected by the vehicle. The safety barrier is designed to absorb the impacts and redirects the vehicle back into the carriageway by breaking back. It should not be designed like a tree, which may destroy and kill the driver.

Therefore, smooth continuity is required for the design of a safety barrier. For example, the end of the safety barrier is designed fairly away so as not to spear the vehicle. The safety barrier is also designed to cover the edge of structures like a tunnel, a bridge, or a lighting pole so that a deviated vehicle from the carriageway would not hit it directly. End treatment of safety barriers forms an integral part of the safety measures.

Covering the edge of bridge and tunnel



Covering a lighting pole

Safety barrier should be a protector not a destroyer

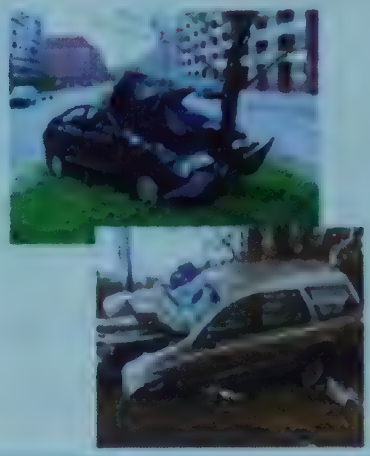


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Figure 4-14: Safety Barrier Protection

5) Measures for Animal Crossing

From environmental and road safety points of view, highway and wild animals should be live together in the same space. However, actually, as many as 25,000 animals are killed on Japanese expressways annually, this is 100 times larger than that of human death on expressways. It is surely a calamity for animals, but it also brings drivers into dangerous situations because many of the drivers who hit animals try to dodge them and lose control of their vehicles.

This is also a case that a car tried to dodge a fox that had strayed off onto highway, and then lost control and hit the median to come to stop on the carriageway. Immediately, after this, the car was collided from the rear by another car following the vehicle and then three people were killed. The section of the highway of the case had a barbed wire to fend off dears but the size of the mesh was too large to prevent a fox to stray in. When highway engineers and operators implement measures for wild animals, detailed surveys such as what kinds of animals are targeted should be carried out.

As a social responsibility of road operators, the protection of wild animals and safety measures for drivers should properly be provided. The fencing cordons off not only animals but also people mistakenly or maliciously trying to enter RoW of the highway.

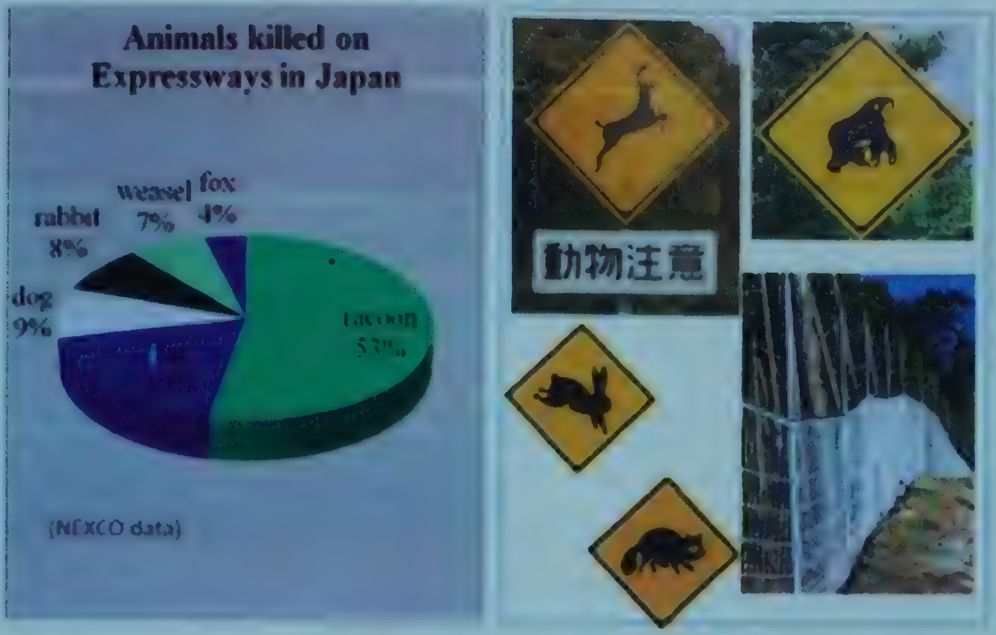

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Figure 4-15: Measures for Animal Crossing

6) Fence crossing Roads and Railways and Boundary Fence

The purpose of the installation of fences against falling objects is the prevention of objects falling from over-bridges down to highways or the prevention of objects from jumping beyond the vehicles on highways to areas adjacent to the highways, in order to ensure traffic safety.

Fences to prevent objects falling from over-bridges should be installed on 1) major roads, 2) over-bridges in densely populated areas used by a large number of people and vehicles, and 3) over-bridges designated as school-commuting roads.

Fences to prevent objects falling off expressways should be installed on 1) sections crossing or nearing railway, 2) sections crossing or nearing heavily trafficked trunk roads, and 3) sections in the vicinity of housing areas. Boundary fences are installed to prevent unauthorized people or animals from entering the highway and to prevent encroachment on right-of-way. Boundary fences should be installed on 1) sections where other roads are adjacent to the highway, 2) sections housed adjacent to the highway, 3) sections with a less-than-3-m difference in elevation between the highway and the outside land, 4) around such facilities as interchanges or service areas, and 5) areas under viaducts.

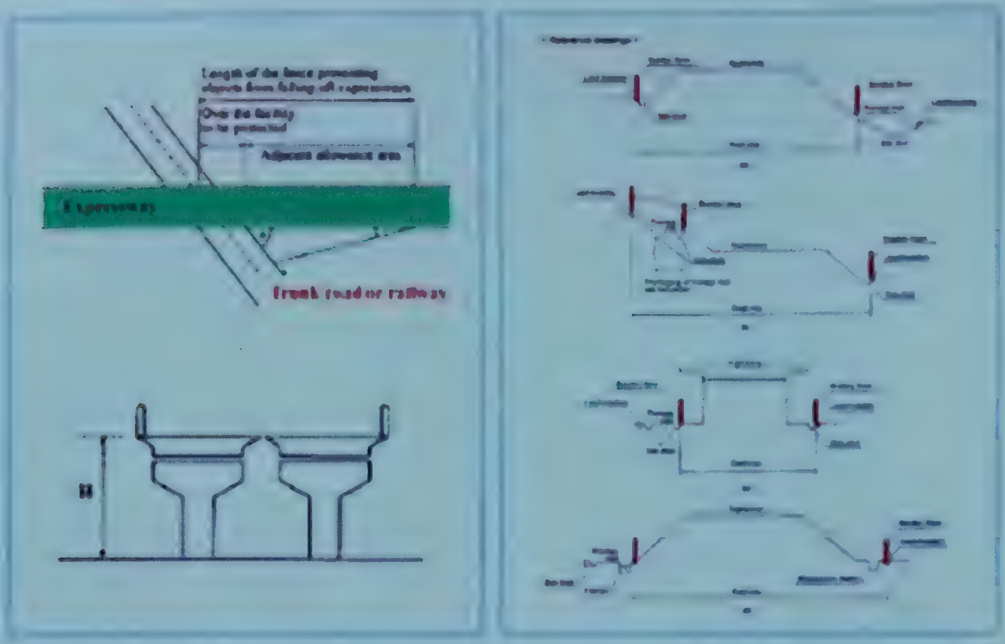
Length of the fence preventing objects from falling off expressway
Over the facility to be protected
Adjacent allowance area
Expressway
Trunk road or railway
H

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Figure 4-16: Fence crossing Roads and Railways and Boundary Fence

7) Wire rope

In two-lane road, it is efficient that installation of wire rope at the median strip.

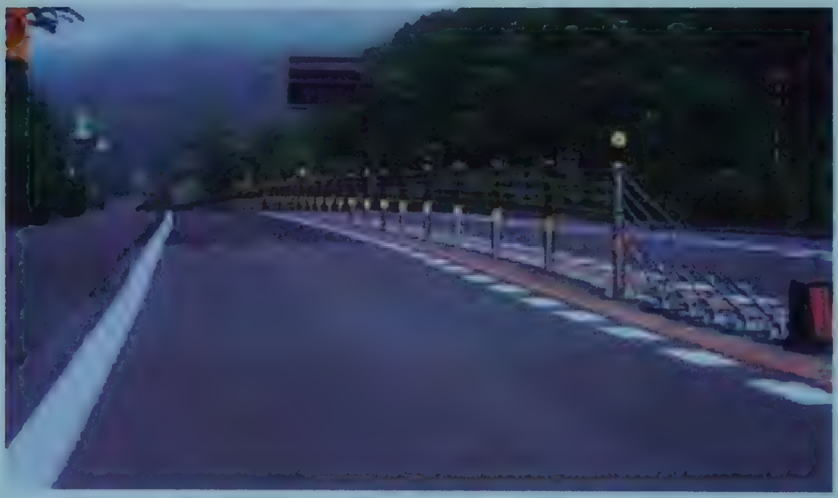

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Figure 4-17: Wire Rope

4.5 Road Safety Devices

4.5.1 Road Signs

It shall refer to the sections on "Traffic Control Devices" (Section5, IRC:SP:55-2014). Work zone signs efficiently convey both general and specific messages using words or symbols and have the same three categories as in a normal highway, viz. (i) regulatory; (ii) warning; and (iii) informatory/guide signs. The regulatory signs used in temporary traffic management plans contain Normal Regulatory signs and Work zone Regulatory signs. The warning signs are also classified as normal warning signs and work zone warning signs. The informatory/guide signs provide road users with critical information on traffic management at work zones.

[14]

4.5.2 Lighting Devices and Variable Message Signs

Lighting devices should be implemented in work zones along with engineering judgment. When they are used to supplement channelization, the maximum spacing for warning lights should be identical to the channelizing device spacing requirements. According to Section5, IRC:SP:55-2014, four types of lighting devices are commonly used in work zones such as floodlights, flashing warning beacons, warning lights, and steady-bum electric lamps. In addition to the above, this guideline showcases some good practices in Japan as follows:

[14]

(1) Lighting Doll of the Balloon

The lighting doll of the balloon is a humanoid safety device of an air balloon, which is easy for road users to see during both daytime and nighttime. Due to the lightweight body of the air balloon, the lighting doll is also very easy to carry. Examples are in Figure 4-18 and Figure 4-19.

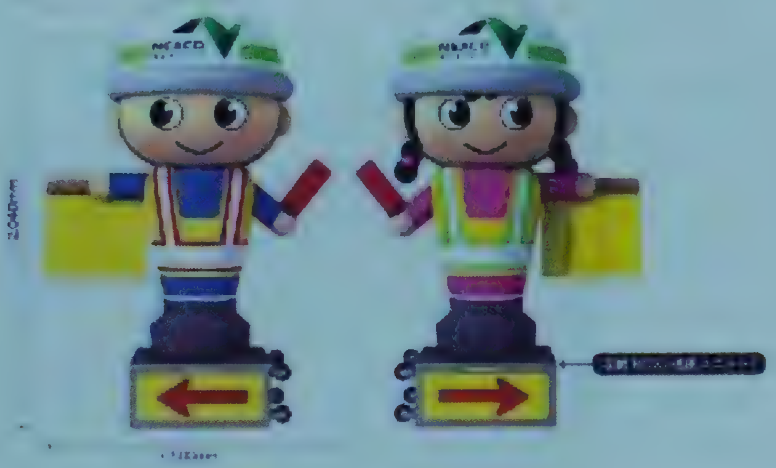

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Figure 4-18: Lighting Doll of Balloon

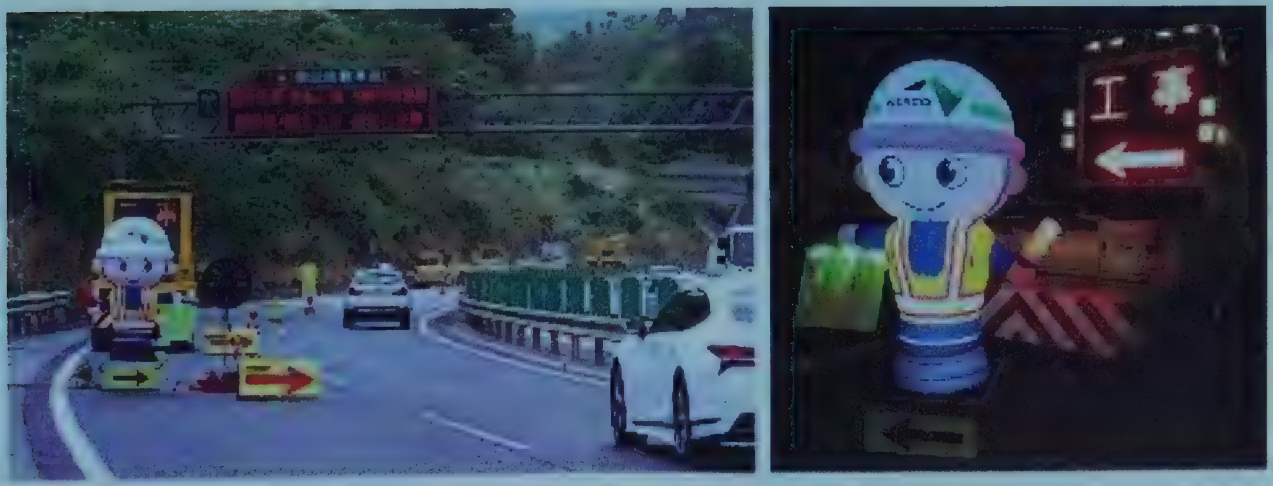

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Figure 4-19: Installation of Lighting Doll

(2) Lighting Tube

Lighting tube makes drivers recognize the work zone during nighttime (See Figure 4-20).

Source: JICA Expert Team

Figure 4-20: Lighting Tube

(3) Traffic Sign Vehicle

A traffic sign vehicle attaches a large visible message sign on its back, which attracts attention from approaching vehicles to a work zone, thereby ensuring safety on the road ahead(See Figure 4-21).

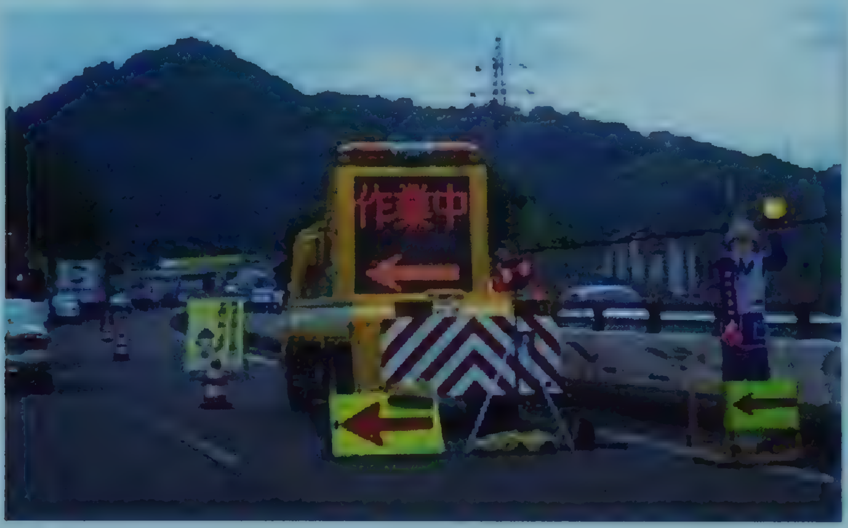

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Figure 4-21: Traffic Sign Vehicle

4.6 Measures for Vulnerable Road Users

It shall refer to the sections on "Measures for Vulnerable Road Users (VRUs)"(Section6, IRC:SP:55-2014).

[14]

4.7 Traffic Management Practices at Worksites

It shall refer to the sections on "Traffic Management Practices at Worksites" (Section7, IRC:SP:55-2014).

[14]

CHAPTER 5 INSPECTION AND DETAILED INVESTIGATION

5.1 Introduction

Inspection is the key to the success of maintenance because it is only through inspection that defects are revealed and then following evaluation and assessment of inspection reports, maintenance planning, and maintenance measures are properly performed. It is important to know what is to be looked for through inspection, how it should be carried out, and what should be its frequency. Evaluation and assessment of inspection reports may reveal the appropriate timing of intervention, the need for further survey, investigation, and testing, and the manner in which existing defects and deficiencies or rectification measures undertaken previously are behaving. An appropriate maintenance plan is carried out for maintenance measures, which shall be based on previous evaluation and assessment steps. In the context of mountainous highways, high pier bridges and structures over steep slopes are widely adapted, and therefore, accessibility to inspection target, which is to be inspected by inspectors or robots, is a vital factor for the implementation of efficient and effective inspection. In this regard, an adequate inspection facility, such as a bridge inspection passage, should be designed in the DPR preparation phase. Also, the arrangement of a bridge inspection vehicle which allows inspectors to access under bridge slab, etc., and the area outside the reach from inspection passage may be a practical solution for this purpose. This guideline aims to present an overall picture and details of inspection and to supplement detailed work processes in a comprehensive manner.

5.1.1 Concept of Maintenance Cycle

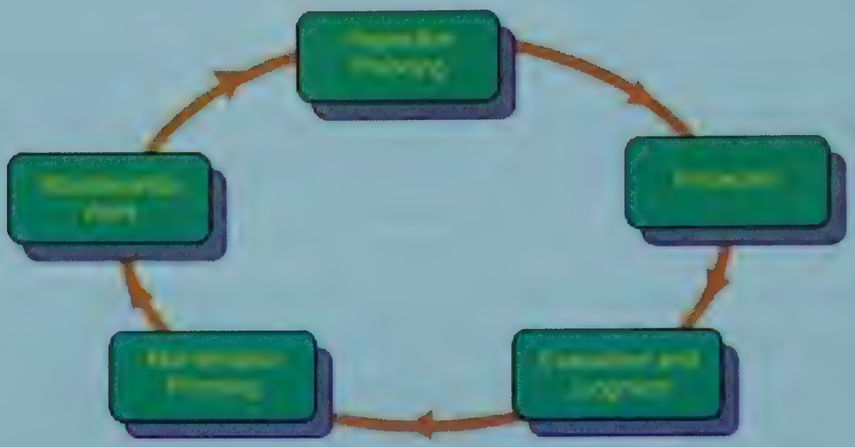
Maintenance is continuous in nature and requires round-the-clock supervision with the following objectives.

- To find the defects quickly, ensure road safety, and prevent the damage/ discomfort to road users as well as a third party (if any)
- To understand/appreciate the deterioration mechanism in order to plan and execute long-term / short-term measures.
- To provide riding comfort to road users round the clock.

The quality of maintenance work and the process can be improved by utilizing PDCA (plan - do - check - act) cycle, which is often used in business process improvement. The concept of PDCA is based on the scientific method, which applies "hypothesis" - "experiment" - "evaluation" or plan, do, check and act. PDCA should be repeatedly implemented in spirals of increasing knowledge of the system that converge on the ultimate goal, each cycle closer than the previous.

A fundamental principle of PDCA is iteration - once a hypothesis is checked after the implementation, executing the cycle again will extend the knowledge further. Repeating the PDCA cycle can bring us closer to the goal, usually perfect maintenance and output.

This approach is based on the belief that our knowledge and skills are limited, but improving. Especially at the start of a project, all of the key information may not necessarily be known. PDCA process provides feedback to justify our maintenance plan based on the inspection results. By checking and analyzing the plans and the results, it improves inspection skills, evaluation of inspection data, planning maintenance works, and execution of maintenance.



Source: JICA Expert Team

Figure 5-1: Concept of Maintenance Cycle

5.1.2 Categories of Inspection

Inspection is classified into five categories according to its purpose, method, and frequency; initial inspection, daily inspection, periodic inspection, detailed inspection, supplemental inspection, and emergency inspection.

(1) Initial Inspection

The initial inspection is performed to identify the initial condition of structures subsequent to the completion of construction. Initial inspection basically records deformation, disaster, and repair history conducted during the construction phase. The record of the initial inspection is to be utilized during the operation and maintenance phase. The initial inspection is also performed, in case a major renovation work or upgrading work is conducted, such as any change or addition of bridge structure system. The inspection method is conducted by close visual check or check from a distance, along with hands-on examination, hammering, and/or non-destructive inspection, where necessary, as listed in Table 5-1. Considering the purpose of the initial inspection, results of inspection shall include any record of deformation, damage, repair, restoration, and/or affected disaster during construction state, if any, and they shall be compiled adequately so that the results can be effectively utilized during the following operation and maintenance stage.

(2) Daily Inspection

Daily inspection is carried out on a daily/weekly basis to identify road conditions and traffic conditions. It shall be a visual inspection carried out from a moving inspection vehicle with the occasional need for observation on foot. The inspection should be done during daytime and nighttime. It usually consists of a team of two inspectors. An example of a routine inspection vehicle is shown in Figure 5-2. For safety purpose, an inspection vehicle should be painted with distinct color such as yellow and has a flashing beacn on top of the roof, which can be easily detected by road users.

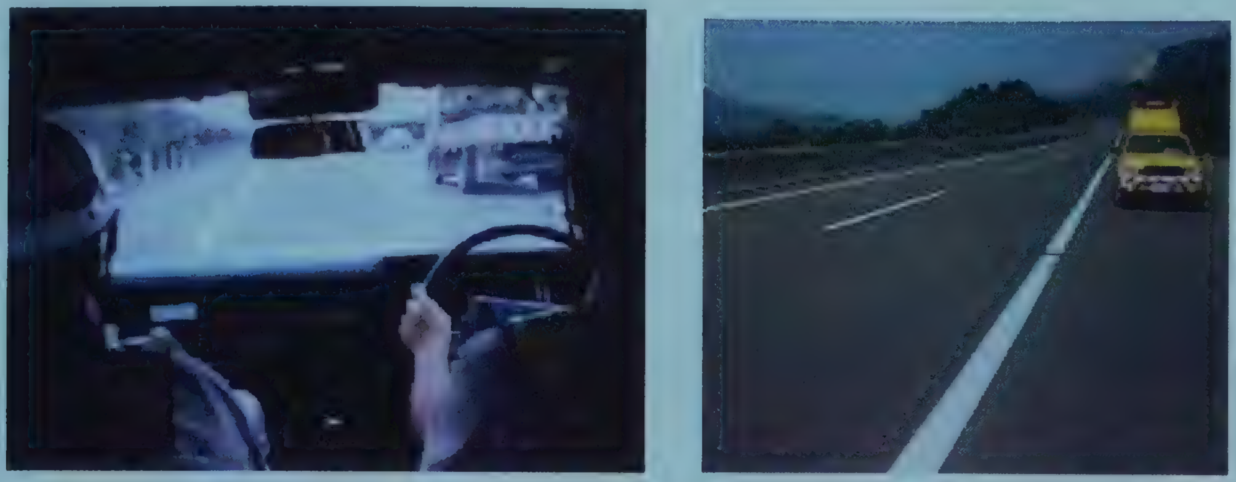


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Figure 5-2: Daily Inspection

(3) Periodic Inspection

Periodic inspection is performed once a year to check the condition of structures in order to prevent any damage to the third party before it happens and to understand the overall structure condition throughout a route(s) under the jurisdiction in order to formulate maintenance planning. It is typically conducted by inspectors walking along targeted highways, which confirms road asset condition, structures crossing other roads, and roadside areas. Periodic inspection should be conducted in an appropriate season so that inspectors do not interfere with luxuriant weed or accumulated snow. Figure 5-3 shows that some distress is observed during a periodic inspection. A team of engineers and technical staff are looking for the distressed areas and testing the concrete by a hammer.

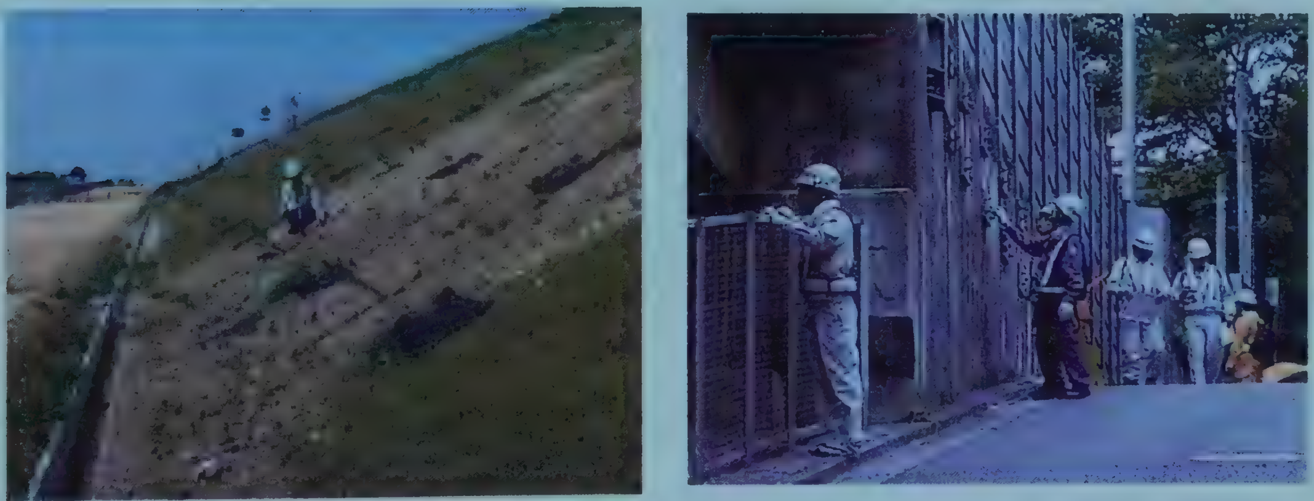

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Figure 5-3: Daily Inspection

(4) Detailed Inspection

Detailed Inspection is primarily designed to (a) carry out the more detailed periodic investigation of structures, and (b) monitor the condition of defects noticed during daily/periodic inspection to ascertain appropriate timing of intervention. A detailed inspection is usually carried out on foot. Some examples of detailed inspection are illustrated in Figure 5-4 and Figure 5-5. Figure 5-4 shows that inspectors are measuring the gap in the bridge joint. If it is acceptable for the ambient temperature, it would indicate the proper functioning of the joint. If the gap is closed or too wide, this will be symptomatic of distress and needs detailed investigation. Figure 5-5, on the other hand, shows that a spall of concrete is noticed in the girder. The concrete condition is being inspected by the hammer in the vicinity of the distressed area.

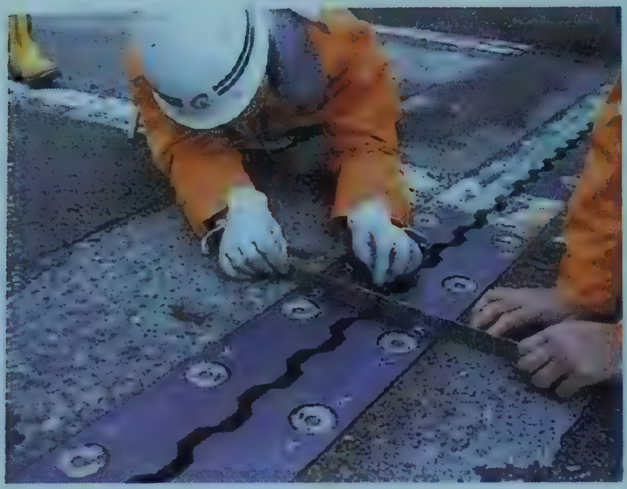

Figure 5-4: Inspection of Expansion Joint

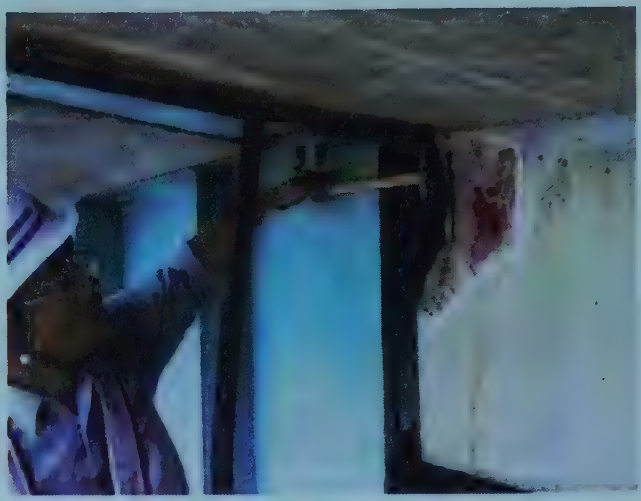

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Figure 5-5: Inspection with Hammer

(5) Emergency Inspection

Emergency Inspection is conducted to investigate the soundness of structures when an emergency situation happens such as earthquake, inclement weather, disaster, major accident, etc. An example includes inspection for eroded slope in the occasional cases of the storm and heavy rain, as shown in Figure 5-6.

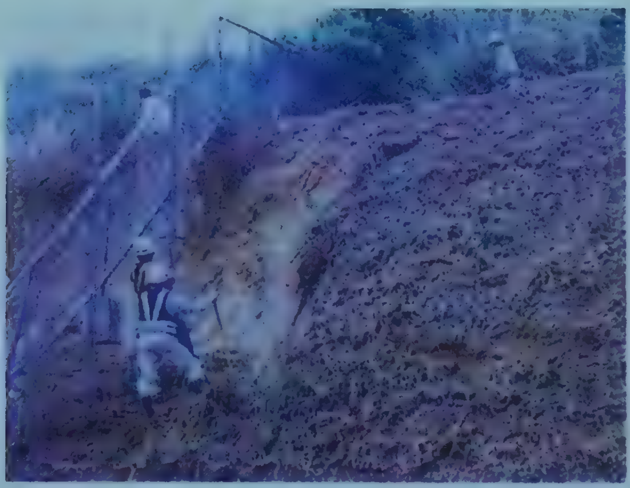

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Figure 5-6: Emergency Inspection for Slope Erosion

Table 5-1 summarizes the purpose, standard methods, and frequency of each type of inspection. Details of inspection methods are elaborated in Section 5.1.3. A road administrator shall determine inspection frequency in consideration of traffic volume, past inspection result, structure condition, environmental condition, and inspection target. In Japan, frequency is typically determined according to traffic volume and type of daily inspection, as shown in Table 5-2.

As for the inspection method of "visual check from a car", more frequent inspection should be conducted on a route with higher traffic volume, since such a route is more likely to be affected by deformation and damage caused by heavier traffic. Nonetheless, inspection should be flexibly intensified regardless of the frequency listed in Table 5-2, considering site conditions.

In other words, traffic volume fluctuates by the season of the year, and during the busy holiday season, more frequent inspection is recommended to tackle the higher possibility of damage or deformation by increased traffic. Moreover, during bad weather, there is a higher risk of road damage by infiltration of rainwater into the ground, and thus, a higher frequency of inspection is recommended.

Table 5-1: Standard Inspection Method

Category of Inspection	Purpose	Inspection Method	Frequency
Initial Inspection for Earth Structure	- To identify the initial condition of structures	- Close visual check or visual check from a distance - Hands-on examination, hammering, non-destructive inspection, where necessary	- Before opening to traffic - At the time of changing structure system
Initial Inspection other than Earth Structure	- To identify the initial condition of structures - To identify soundness	- Close visual check or visual check from a distance - Hands-on examination, hammering, non-destructive inspection, where necessary	- Before opening to traffic - At the time of changing structure system
Initial Inspection other than Earth Structure (for the purpose of securing safety and prevention of third party damage)	- To identify the initial condition of structures - To identify soundness - To prevent third party damage	- Basically close visual check or visual check from a distance - Non-destructive inspection, where necessary	- Before opening to traffic - At the time of changing structure system
Daily Inspection	- To confirm safety on a daily basis	- Combination of a visual check from a car physical sense of an inspector from a car, visual check from a distance - Observation on foot, where necessary	- Depend on traffic volume 4 days+ / 2 weeks 5 days+ / 2 weeks 6 days+ / 2 weeks 7 days+ / 2 weeks
Periodic Inspection	- To confirm the safety - To understand overall road condition under the supervision - To prevent third party damage	- Visual check from a distance or close visual check	1 time + / year
Detailed Inspection	- To identify soundness	- Close visual check - Hands-on examination, hammering, and non-destructive inspection, where necessary	1time + / 5 years
	- To identify soundness - To prevent third party damage	- Close visual check and hands-on examination/hammering - Non-destructive inspection, where necessary	1time + / 5 years
Emergency Inspection	- To identify the condition of the structure in an emergency situation - To identify the similar structure	- Combination of a visual check from a distance, close visual check, hands-on examination, hammering - Non-destructive inspection, where necessary	As necessary

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Table 5-2: Frequency of Daily Inspection (Reference)

Inspection method	Frequency	Traffic volume etc.
Visual check from a car	More than 4 times / 2 weeks	Less than 25,000 vehicles/day
	More than 5 times / 2 weeks	From 25,000 to 50,000 vehicles/day
	More than 6 times / 2 weeks	From 50,000 to 80,000 vehicles/day
	More than 7 times / 2 weeks	Equal to and more than 80,000 vehicles/day
Night inspection	More than Once a year	-
Observation on foot	More than Once a year	Inspection target: Sign board, bridge joint
	More than Twice a year	Inspection target: Overpass, Interchange bridge, Junction bridge

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5.1.3 Basic Framework of Inspection

(1) Inspection Method

Proper and efficient inspection methods shall be chosen in consideration of the purpose of inspection and targeted structure.

- Visual check from a car

This method is performed on a daily inspection in order to identify road conditions and traffic conditions visually from a moving vehicle. If inspectors find any abnormal situation, it is necessary to stop a vehicle on a shoulder for more accurate observation of such situation on foot.

- The physical sense of an inspector from a car

This method is to inspect road conditions by the feeling of inspectors (i.e. through the vibration of a vehicle) riding on a moving inspection vehicle.

- Visual check from a distance

This method is to inspect structure conditions from a distance by bare eye or by binocular.

- Close visual check

This method is to get close to structure within inspectors' arm reach and to examine by bare eye and hands. In case there is an inspection facility available (e.g. inspection passage for bridge), an inspector can access a targeted inspection point by the facility. In contrast, if there is no inspection facility and thus evaluation by bare eye is difficult, road administrator shall secure adequate means of access method to the inspection target such as bridge inspection vehicle so that inspectors can get close to targeted inspection point.

- Hands-on examination

This method is to examine an inspection target by hand in order to identify its defect and deformation condition. In particular, inspectors look into whether there is any occurrence of crack, fracture, looseness, dropout, or deformation in the place of attachment of bracket, anchor bolt, bolt, and nut. Moreover, inspectors confirm whether the attachment of accessories such as anchor bolts, bolts, and nuts is sufficiently fixed or not by shaking the inspection target (i.e. unstable condition, loosened attachment, etc.).

- Hammering

This method is to hammer inspection target with a hammer in order to identify structure condition; specifically, stripping, flaking, and loosened ·bolt. Especially, an inspector shall hammer very carefully around the area where deformation is identified by close visual check, where deformation is repaired or reinforced, a crown of tunnel lining, the area around joint, construction joint, and edge. Traditionally, a hammer with a weight of around 230 grams is used for this hammering method. The evaluation of hammering is typically carried out by the sound which occurs by knock of a hammer to an inspection target, as shown in Table 5-3. Inspector shall not hamper very strongly so as not to damage the inspection target.

Table 5-3: Guidance of Evaluation according to Sound by Hammering

Result of hammering (sound by a hammer)	Estimated condition of an inspection target
Crisp, high piercing sound, and sense of good rebound from the inspection target	No damage/deformation
Dull sound	Deteriorated, the existence of cavity near the surface
Sound with the sense of thinness (dull sound)	Stripping, flaking

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- Non-destructive inspection method

Inspection of existing road structures shall minimize influence not only to road users but also damage to the structures. Various types of non-destructive inspection equipment have been developed in recent years and are being utilized to examine the soundness of road structures.

For adaption of these methods, the inspector shall thoroughly understand specification, accuracy, usage method, and limitation of accuracy guarantee as well as deformation of each structure, usage condition, and environmental condition. Needless to say, it is very important to utilize equipment under proper use conditions.

A most versatile and simple tool is a hammer. The sound produced by knocking the surface of the structure reveals faults. Rebound hammers can estimate concrete compressive strength by knocking the surface. Optical fiber scope is used to visually check the interior of small spaces. Advanced technologies such as radar, infrared, high-resolution cameras, X-rays, etc., are being used to quickly and accurately examine the hidden defects under the surface of structures.

(2) Inspection Frequency

The speed of deterioration is different for each structure, depending on design condition, construction quality, surrounding environment, and load affecting it. The frequency of inspection has to be decided individually especially for important structures. The typical frequency of inspection is listed in Table 5-4. It is important to establish how often inspection shall be conducted in a sound manner in order to ensure that each inspection is followed up with appropriate action systematically.

Table 5-4: Frequency of Inspection

Type of Inspection	Frequency
Initial inspection	- Just after the completion of construction of the targeted structure, prior to opening to traffic - In case major renovation work is performed and the structure system is altered
Daily inspection	- Daily/weekly *See below section.
Periodical inspection	- More than once a year
Detailed inspection	- More than every five years - Detail inspection of slopes should be performed within two years after the completion of the construction phase. This is because typically slope failures are more likely to occur within five years after the end of the construction phase.
Emergency inspection	- in case of necessary/additional/ad-hoc requirements/situations, such as earthquake, inclement weather, disaster, and major accident

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5.1.4 Inspection Planning

An inspection program shall be set up before carrying out any periodic inspections. The inspection program shall contain the following items:

i) Types of inspection
ii) Objects/components and items
iii) Time schedule and inspection route
iv) Members of an inspection team
v) Inspection methods
vi) Tools and equipment
vii) Inspection Record

The details of inspections shall be recorded in a systematic way using typical forms used for recording the inspections observations. Inspectors shall be equipped with appropriate tools and equipment. The tools listed in Table 5-5 are usually carried out by inspectors in the inspection vehicle. To secure safety for inspectors and general traffic, traffic safety equipment such as safety cones and a flag should be arranged.

Table 5-5: Recommended Tools and Equipment in accordance with Inspection Type

Type of inspection	Tools and equipment
- Daily inspection - Emergency inspection	camera/ video camera, binoculars, compact measuring tape, test hammer, measuring tape, survey pole, black board, chalk, torch light, maps, etc.
- Initial inspection - Periodic inspection - Detailed inspection	camera/ video camera, binoculars, magnifying glass, calipers, clearance gauge, test hammer, measuring tape, survey pole, black board, chalk, spade, rope, torch light, maps, etc.

[16]

Several important points shall be kept in mind for the planning of inspection, as below;

1) If deterioration is caused by the aging of a target structure, it may become easier to understand the progression of deterioration by grasping changes over time with past inspection results or organized records, and thereafter make the content of inspection specific. It is important to collect information as much as possible when performing desk research to prepare an inspection schedule.

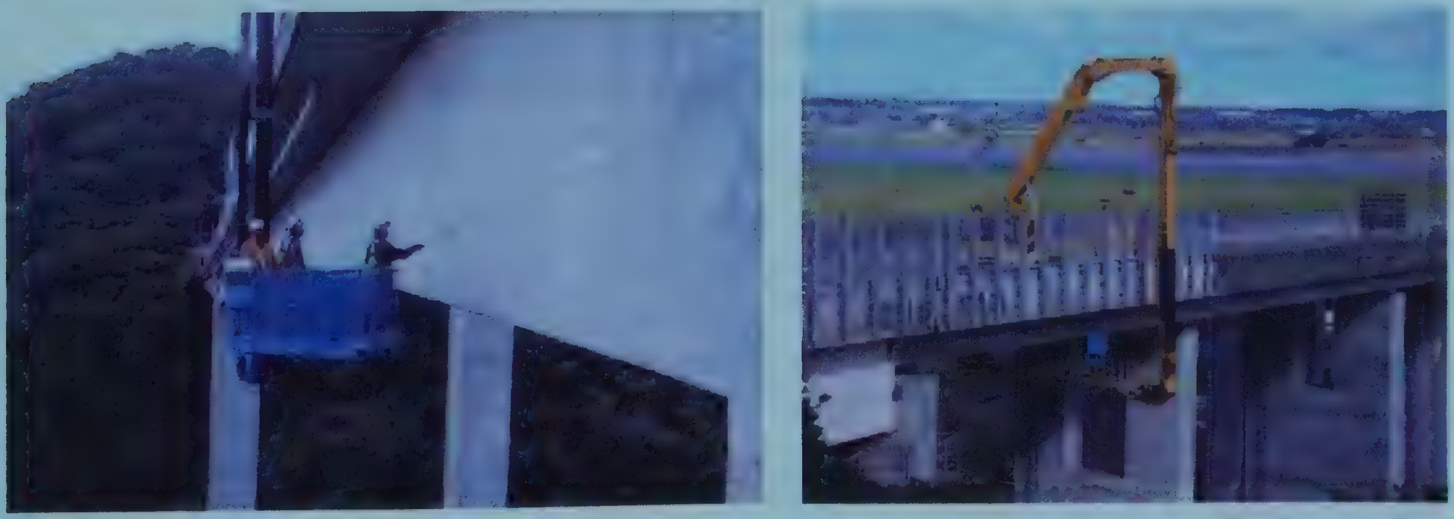
possible when performing desk research to prepare an inspection schedule. Where necessary, it is recommended to understand issues by hearing comments from skilled engineers.

2) Issues, investigation methods, and scope shall be considered prior to the development of investigation planning. In particular, when a continuous follow-up investigation is performed, it is necessary to plan an investigation without deficiency of investigation. Although addition or omission on investigation items may occur with the progression of investigation, careful attention shall be always paid so that the purpose of the investigation will not change greatly. In addition, when the investigation is performed by selecting a structure on progression out of the structure with multiple deformations, the investigation shall shift to detailed investigation based on follow-up results.
3) Investigation purpose, items, methods, quantity, and location shall be presented in detail as much as possible. It is important to plan that there will be no reworks in the middle of the investigation. Because an investigation may take place within a restricted area of the service route, constrained conditions related to the investigation shall be sufficiently checked when planning an investigation. In particular, slope investigation sometimes requires traffic regulation and/or a large scale temporally works, and takes time depending on the type of investigations.

5.2 Inspection Path

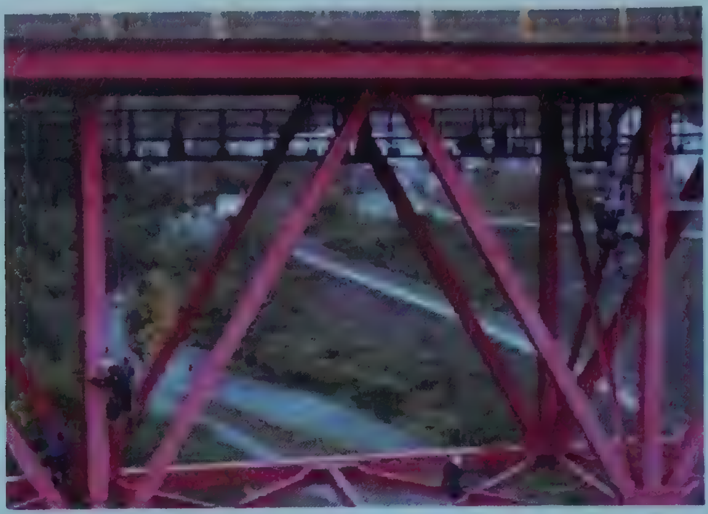
5.2.1 General

A highway in mountainous regions sometimes adapts high pier bridges to overpass steep terrain, which generally makes it difficult for inspectors to access targeted inspection points. In this regard, a bridge inspection vehicle or lope access is commonly introduced, as shown in Figure 5-7 and Figure 5-8. Simultaneously, the tunnel is another type of key structure on mountainous highways. Inspection vehicles are typically used to access the top of the concrete slab inside the tunnel, as shown in Figure 5-9.



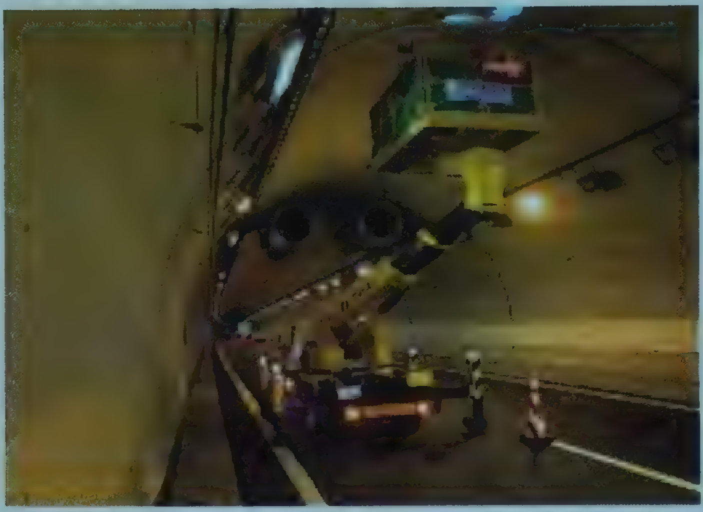
Source: JICA Expert Team

Figure 5-7: Bridge Inspection Vehicle for Inspection of High Pier Bridge



Source: JICA Expert Team

Figure 5-8: Rope Access for Inspection of High Pier Bridge



Source: JICA Expert Team

Figure 5-9: Inspection Vehicle in Tunnel

5.2.2 Consideration of Maintenance on Planning and Design Phase of Structures

In planning and design phase of structures, including those of high pier bridges, long tunnels, and large cutting slopes, it is critical to incorporate the concept of easiness of inspection and maintenance, especially on mountainous highways, while opening the concerned section in a timely manner is always the top priority and maintenance after opening may not be prioritized at the time of construction phase. This is because fundamentally such structures cannot escape from the nature of some forms of degradation in the long term perspective caused by factors of the outside environment and traffic load. Road administrators have a responsibility to ensure the function of structures by periodical inspection, assessment, repair, renovation, and up-gradation. In this regard, the concept of easiness of maintenance should be incorporated in the planning and design phase well in advance of the maintenance stage.

Some good practices are shown as below:

(i) Introduction of the continuous superstructure and rigid-frame structure

In terms of relief of maintenance workload, continuous superstructure and rigid-frame structure can reduce the number of joints and shoes, respectively. Because joints are often major causes to of corrosion and degradation of concrete and shoes around the joints due to seepage water from the bridge deck surface above, the avoidance of such joints by adapting continuous superstructure can lead to a major solution to the issue.

Also, a structure type of rigid-frame structure, which connects superstructure and substructure directly, does not need shoes between them and thus increases the efficiency of inspection. This type of structure can also reduce noise at the location of joints and increase driving comfort.

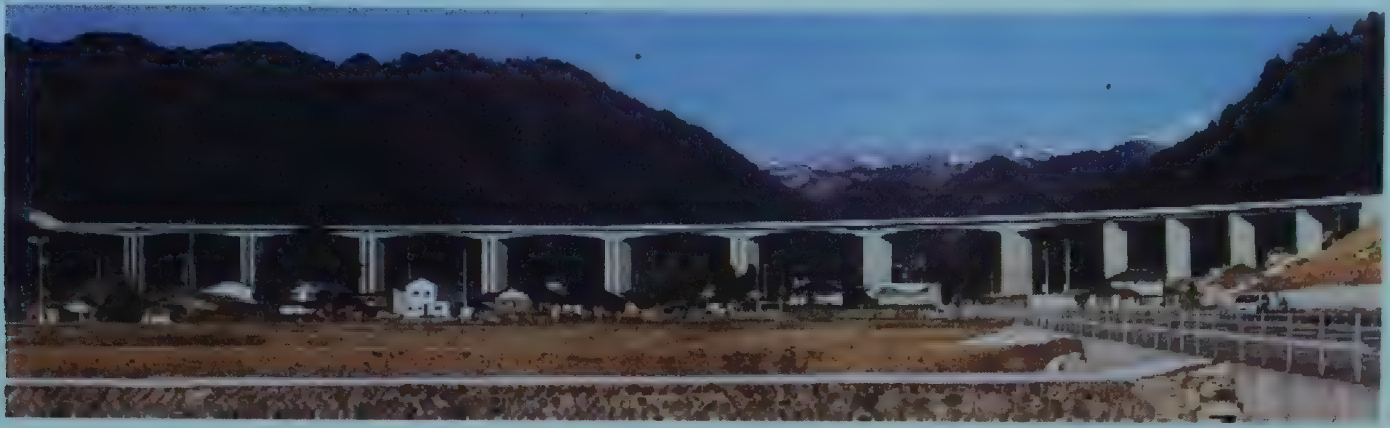


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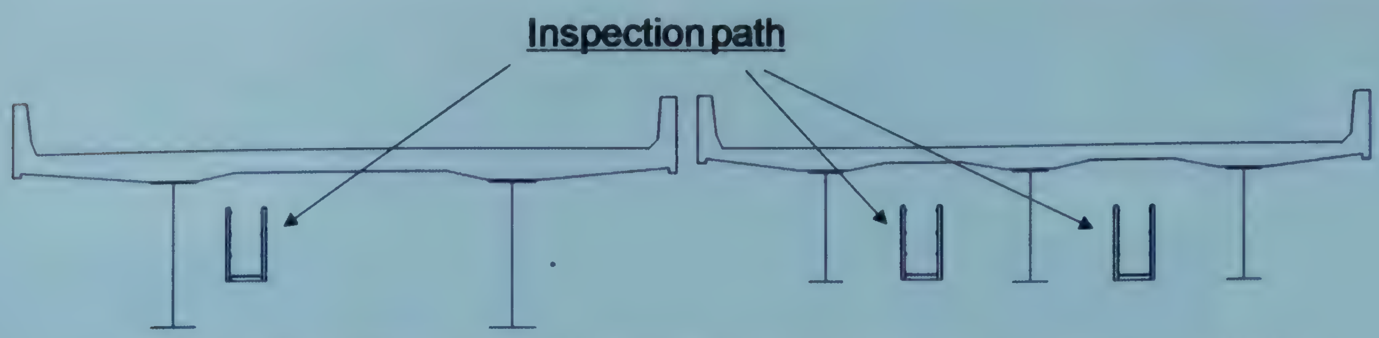
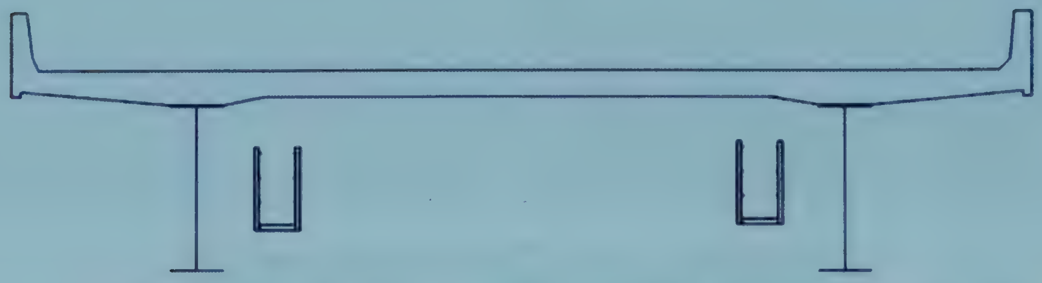
Figure 5-10: Continuous Superstructure with Rigid-Frame Structure

(ii) Installation of Inspection Path

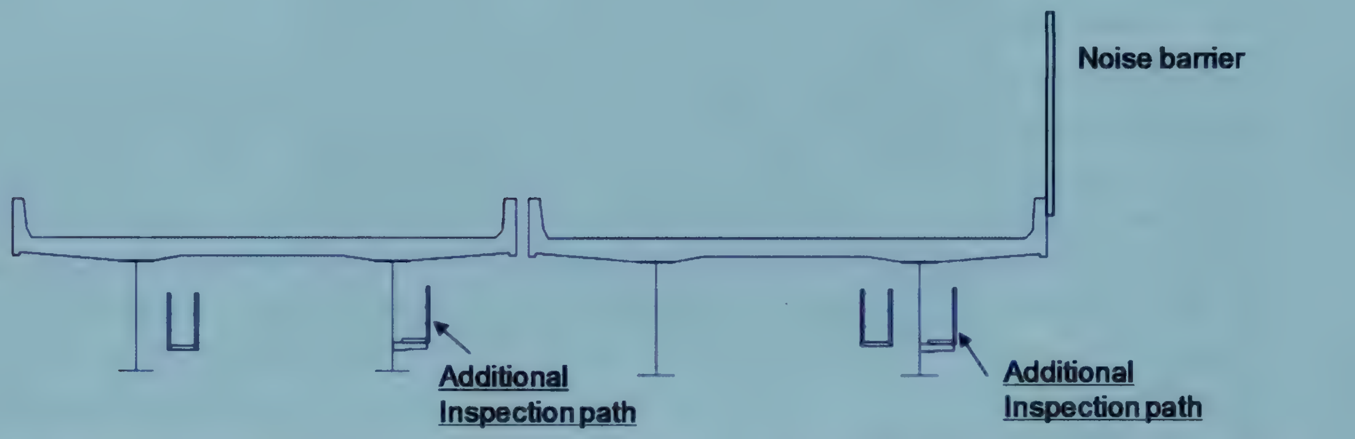
An inspection path is indispensable to maintain structures in good condition. Especially, the points where degradation or deterioration are more likely to happen or where it is more suspectable to earthquake tremor (e.g. bridge abutment), need inspection path so that inspectors can access such points and conduct a close inspection. It is also important that the arrangement and position of the inspection path are well considered so that inspectors can move smoothly without obstruction or hindrance. Figure 5-11, Figure 5-12, and Figure 5-13 show examples of inspection paths for a bridge and a tunnel, respectively. For the details of each design, readers are expected to refer to the concerned guidelines.


Inspection path

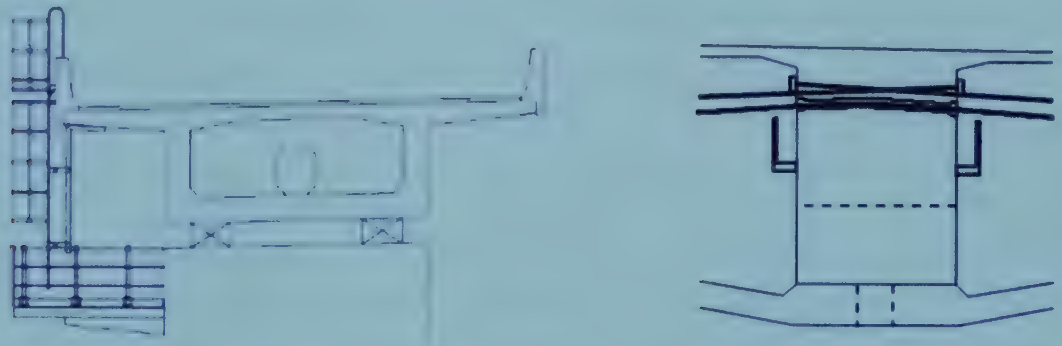
(a) Typical Inspection Path in case Distance between Girders are not Wide



(b) Typical Inspection Path in case Distance between Girders are Wide

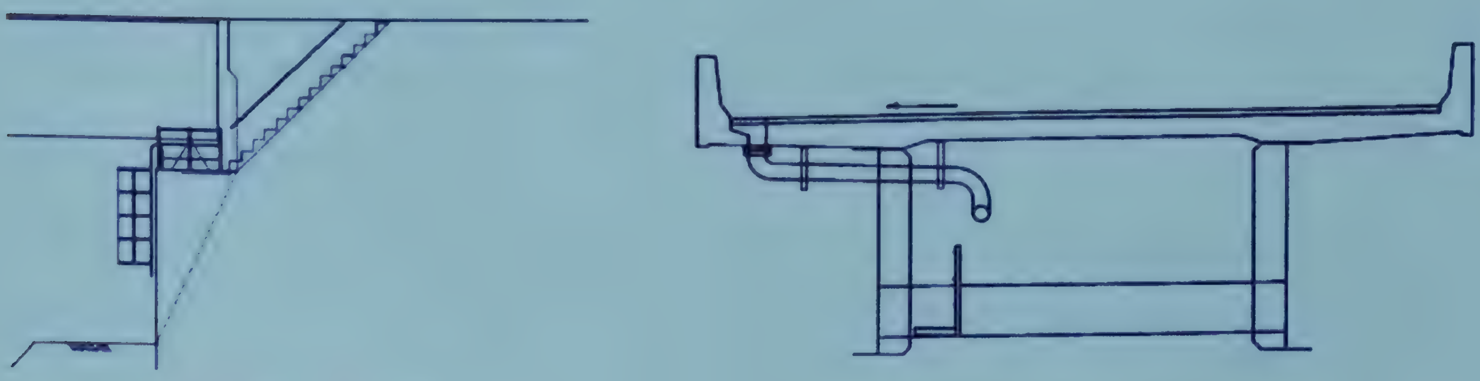

Noise barrier
Additional Inspection path
Additional Inspection path

(c) Additional Inspection Path in case Difficulty of Access Even by Inspection Vehicle



(d) Installation of Ladder at Bridge Joint

(e) PC Cable Anchorage Point



(e) Bridge Abutment

(f) Water Drainage Point

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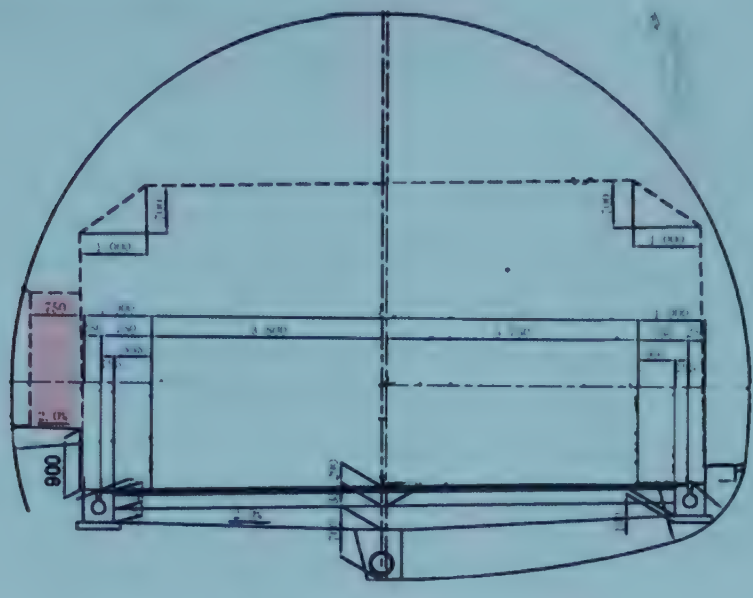
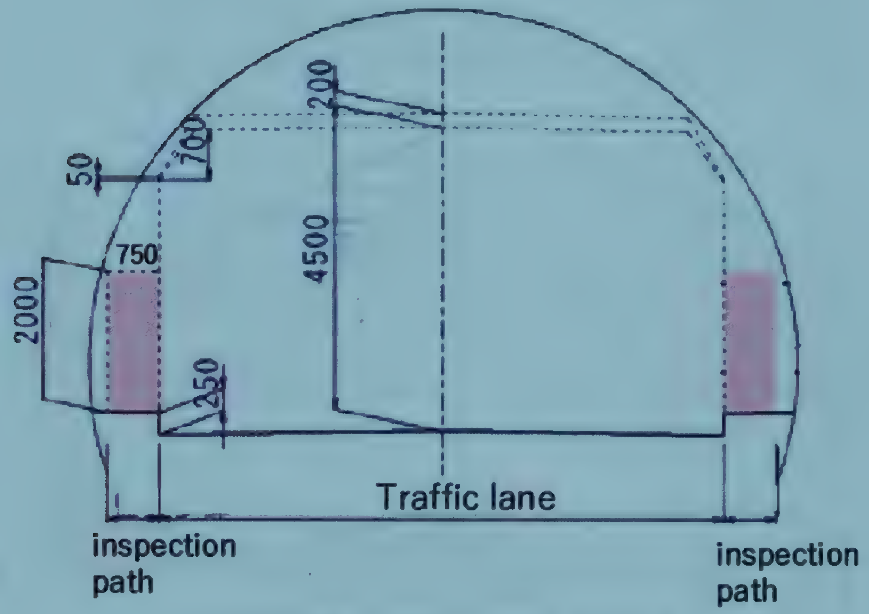
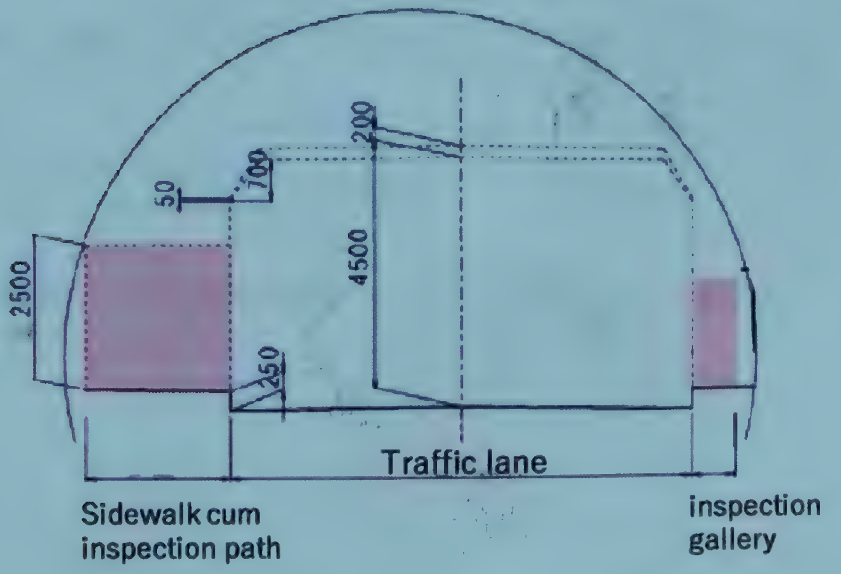
Figure 5-11: Typical Arrangement of Inspection Path for Bridge



(a) Raised Inspection Path


200
700
50
750
4500
2000
250
Traffic lane
inspection path
inspection path

(b) Lowered Inspection Path


200
700
50
4500
2500
250
Traffic lane
Sidewalk cum inspection path
inspection gallery

(c) Inspection Path cum Sidewalk

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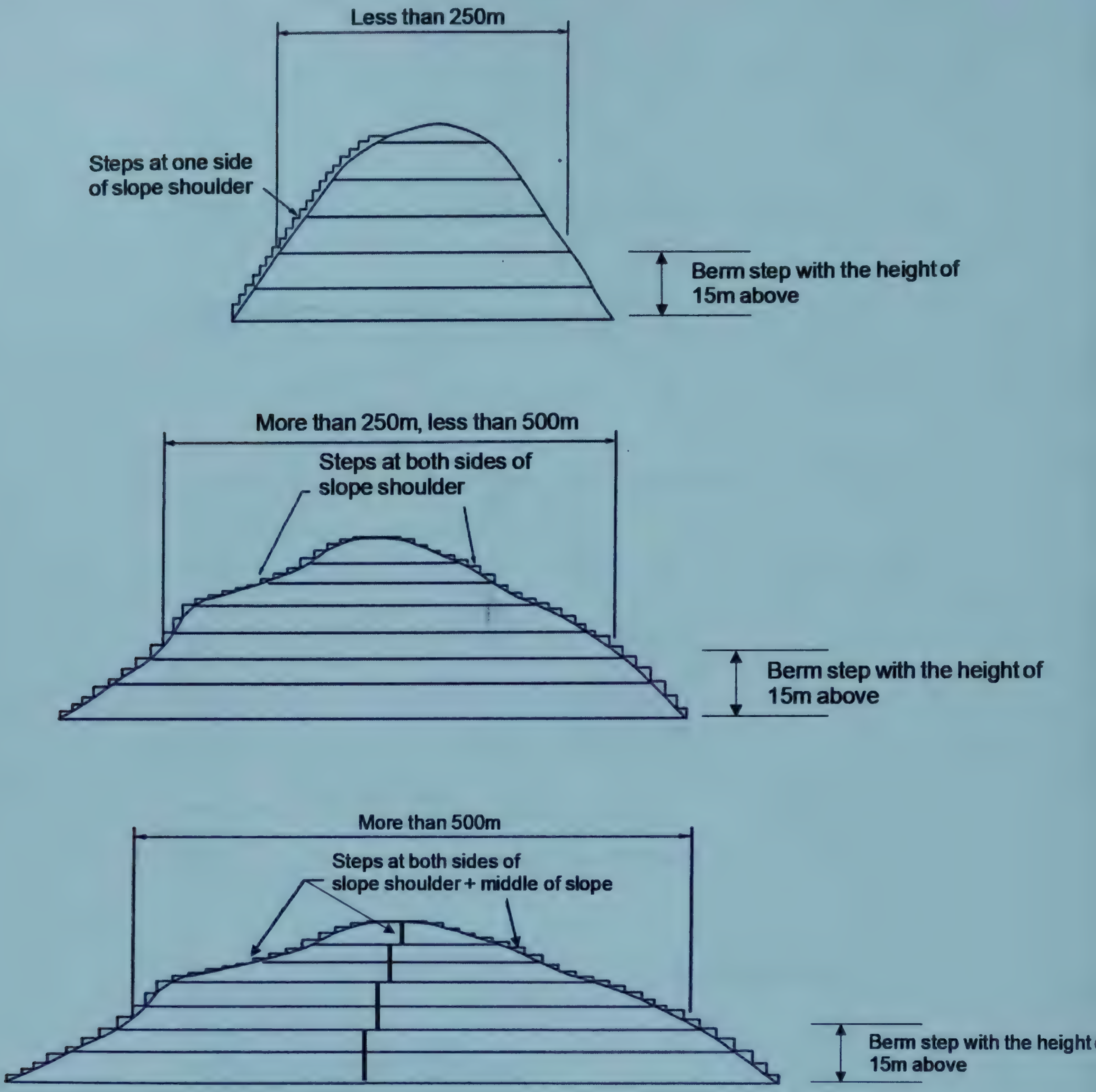
Figure 5-12: Typical Arrangement of Inspection Path for Tunnel


Less than 250m
Steps at one side of slope shoulder
Berm step with the height of 15m above
More than 250m, less than 500m
Steps at both sides of slope shoulder
Berm step with the height of 15m above
More than 500m
Steps at both sides of slope shoulder + middle of slope
Berm step with the height
15m above

Edited from [9]

Figure 5-13: Typical Arrangement of Inspection Path for Slope

5.3 Inspection of Earth Structures

5.3.1 Introduction

Earth structures, such as slope, embankment, and drainage, are key elements of hill roads. It is indispensable to maintain good condition by proper inspection, investigation, monitoring, maintenance work to keep the function of hill roads.

Figure 5-14 shows the number of failures of earth structures, occurred on Japanese expressways from 1993 to 2004, which total number is 2,373. As is identified from the figure, approximately most failures happened within five years from opening to the public. This fact highlights the importance of an inspection for earth structure on new highways just after the opening. In other ways, inspection shall not be exempted for new highways rather shall be meticulously conducted.

Figure 5-15 shows failures by structure type, which reveals that more than 90% of failures are in an embankment and cut slope sections. The past experience shows about half of these failures were triggered by failures of the drainage system.

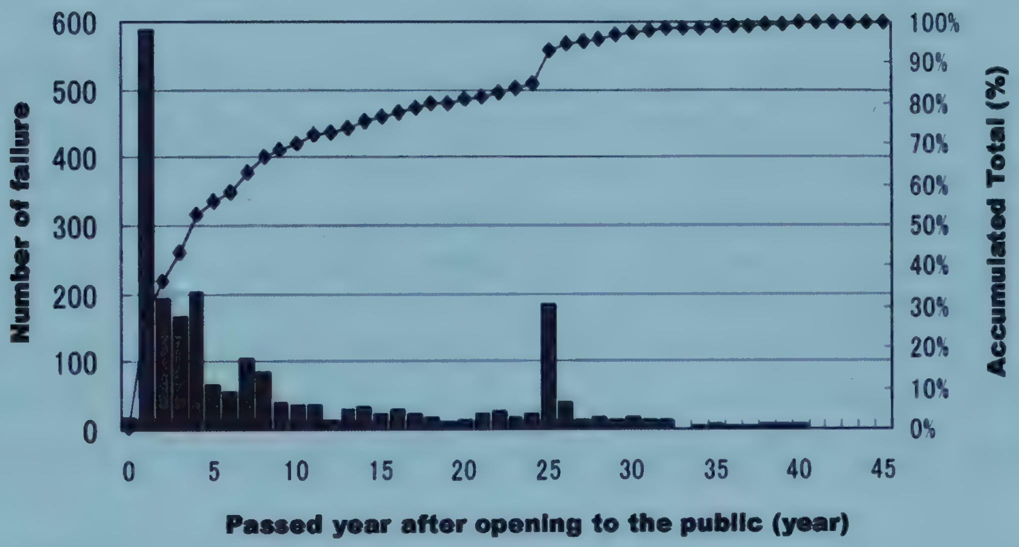


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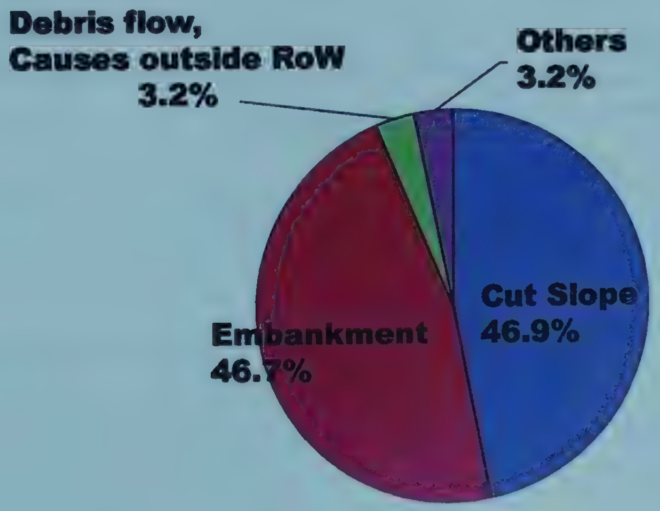
Figure 5-14: Number of Failures for Earth Structures



[16]

Figure 5-15: Failures by Structure Category

5.3.2 Driving Factors of Failures

The driving factors of failures of earth structures are basically classified into two categories, which are (1) internal factors and (2) external factors, as shown in Table 5-6. Since internal factors are the original property of a concerned earth structure, it is recommended to conduct desk research and site survey for an efficient and effective inspection.

Table 5-6: Driving Factors of Failures

Driving factors of failure of earth structure	Internal Factor	Property of material	Soil property, Geology, Material for embankment
		Structure	Strata, Embankment constructed on a slope
		Water	Groundwater
	External Factor	Human factor	Development of surrounding area, change on catchment area, aging of structures
		Rainfall	Rainwater, melting snow
		Earthquake	--

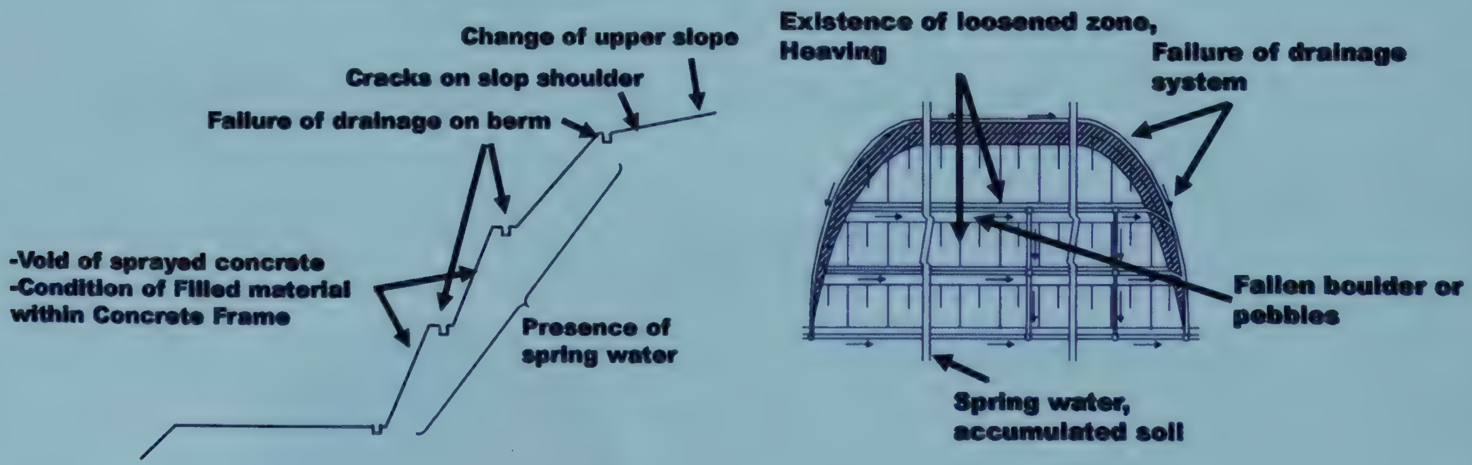
[16]

5.3.3 Basic Points of Inspection

This section highlights basic but important and practical points when conducting an inspection of slope structure. Although it is difficult to predict a small-scale collapse, such as surface failure caused by rainfall, some abnormal phenomena are usually detected before a slope collapses. Therefore, it is necessary to plan a countermeasure before a slope collapses by daily slope inspection, taking into account the important points mentioned below.

(1) Cut Slope

Important points for inspection for cut slope are shown in Figure 5-16 and Table 5-7.


Change of upper slope
Cracks on slop shoulder
Failure of drainage on berm
-Void of sprayed concrete
-Condition of Filled material within Concrete Frame
Presence of spring water
Existence of loosened zone, Heaving
Failure of drainage system
Fallen boulder or pebbles
Spring water, accumulated soil

[16]

Figure 5-16: Important Points of Inspection for Cut Slope

Table 5-7: Important Points for Inspection for Cut Slope

Location	Points to inspect
Upper slope	- Main Scarp - End point of drainage system outside RoW - Land development of upper slope
Shoulder of slope	- Existence and condition of the drainage system on slope shoulder - Existence of vegetation which prefers most and wet places
Slope face	- Deformation of the slope protection structure - Damage, clogging, or ponding of drainage - Spring water from the slope - Existence of vegetation which prefers most and wet places - Straightness of berm - Condition of sealing concrete (deformation, crack, etc.)
Toe of slope	- Deformation or clogging of drainage system - Straightness of location of slope toe
Others	- Deformation or countermeasures of a concerned or adjacent slope in a construction phase - Existence of spring water or failure zones in surrounding areas

[16]

1) Deformation of Slope

- Crack, heaving, and depression

Crack, heaving, and depression, which occur on a concerned cut slope or upper slope, are very critical symptoms for the stability of a slope. Past experience shows that deformation of a slope initially tends to appear as a tension crack or depression on an upper slope, from which a concerned slope fails. Therefore, such a crack or depression implies the possibility of a future failure. Inspectors, therefore, shall conduct inspection not only within a cut slope but also over an upper slope, with paying attention to cracks and depression.

- Slope failure

In case of an inspection for slope failure, inspection shall be done not only for colluvium but also for an adjacent area or upper slope, keeping in mind potential future slope failure. It is recommended to pay attention to the factors of surrounding condition, location, geology, strata, elapsed time after a concerned slope failure, etc.

- Gully erosion

Major factors of gully erosion are soil property (e.g. sandy soil), failure of drainage, slope gradient, failure of vegetation. Assessment should be done from the point of view of slope stability.

- Deposited soil on a berm

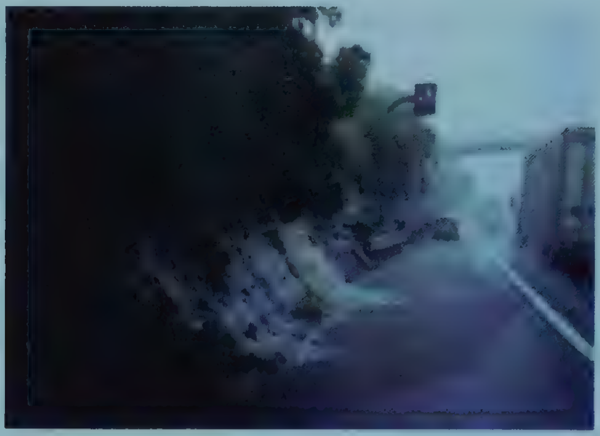
Deposited soil on a berm may lead to failure of drainage on a berm. This should be judged, paying attention to the amount and condition of deposited soil mass, position and width of a berm, size of drainage, and so forth.

2) Spring water

Inspectors shall pay special attention to spring water on a slope or drained water in a drainage system. At a slope where drained water is confirmed at all times of seasons, or spring water is confirmed on a cut slope, the volume of the drained water and groundwater level may increase during and after heavy rain or snow melting season, which may lead to a slope failure.

It is critical to inspect if abnormal drained water, newly emerged spring water, muddy flow, the sharp increase of drained water are on a cut slope since there is the precedent phenomenon of a slope failure. Figure 5-17 shows an example of abnormal spring water.

Figure 5-18 shows an example of abnormal water on a masonry wall. Proper countermeasures such as horizontal drainage borings shall be conducted after due inspection and design. Figure 5-19 shows an example of abnormal drained water from horizontal drainage boring.



[16]

Figure 5-17: Abnormal Spring Water from Slope

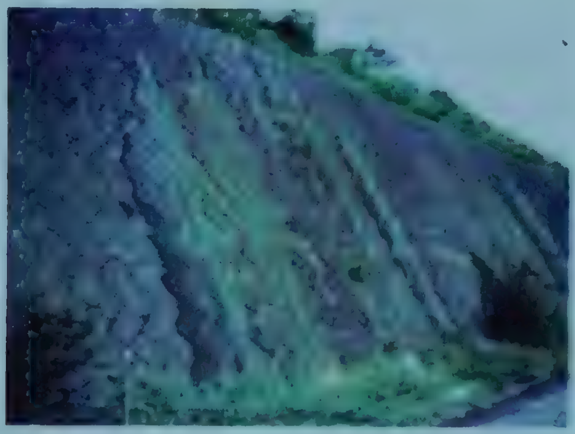


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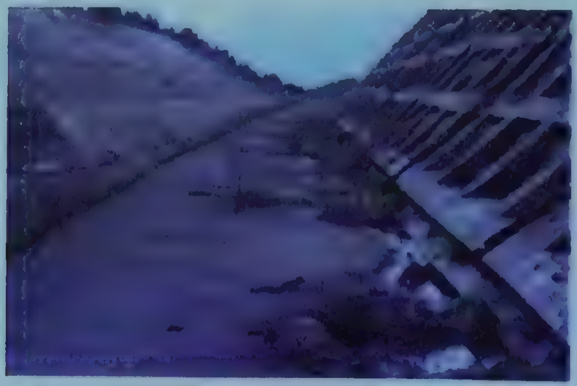
Figure 5-18: Abnormal Water on Masonry Wall



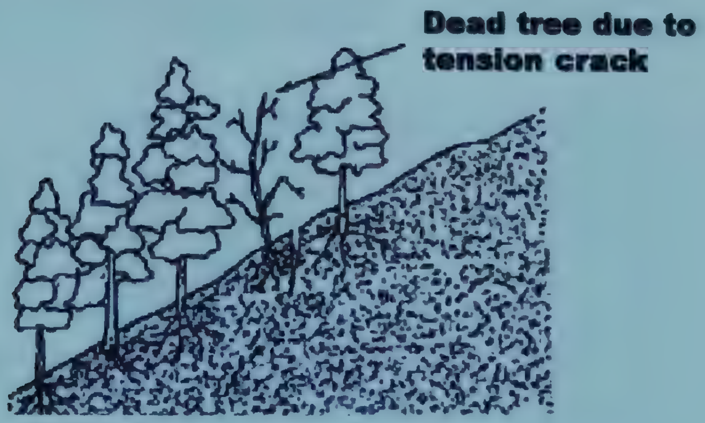
[16]

Figure 5-19: Abnormal Water from Drainage Borings

3) Abnormal vegetation

- Dead trees

A group or line of dead trees implies progress of tension cracks on a sloping ground, which phenomenon is especially serious for a tree which root system is not well developed (See Figure 5-20). Attention shall be paid also for a tree whose upper branches or leaves are dead. Moreover, a location, where a root of a fallen tree causes disturbance of its surrounding ground, is susceptible to the intrusion of rainwater into a slope. This can cause an issue of slope stability.



[16]

Figure 5-20: Dead Tree due to Tension Crack Development on Slope

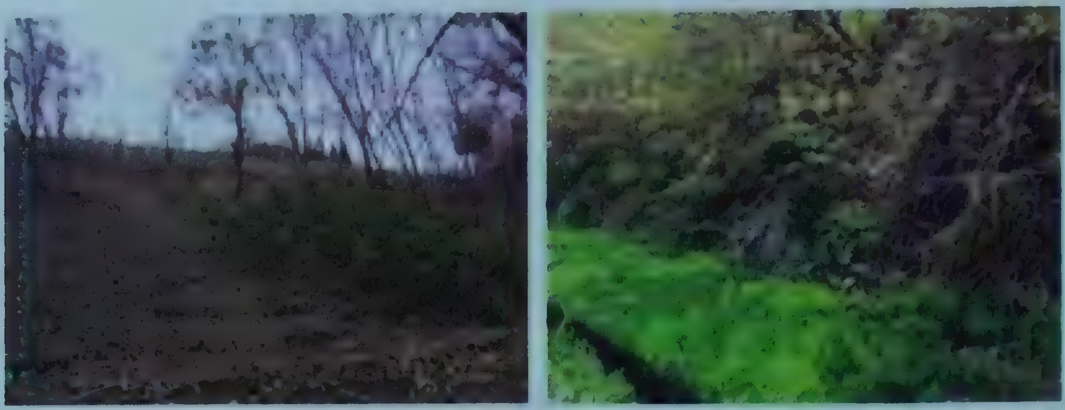
- Failure of vegetation

The main purposes of vegetation are to prevent gully erosion and surface failure. A slope with declined vegetation is facing a risk of gully erosion and surface failure.

- Vegetation which prefers moist and wet places

Bamboo and cedar prefer moist and wet places. If a bamboo grove or a cedar forest is distributed in an area, it implies that there is a large quantity of underground water. In addition, a bamboo grove grows mostly on a moist mountain slope, valley, talus, and debris-flow deposition. Also, cedar is suitable for a humid place as it is said "Grow in the area with unctuous humid soil close to the mountain stream", which means easy to grow on the slope of dip slope. Typical vegetations which prefer most and wet places are listed below:

- Bamboo
- Moss
- Fern
- Euptelea poyandra
- Hydrangea
- Petasites japonicus
- Rhus japonica
- Alnus japonica
- Populus maximowiczii
- Basket willow
- Cryptomeria



[16]

Figure 5-21: Vegetation Growth which Prefers Moist and Wet Places

4) Development of upper slope, or hinterland

Although the upper slope of a cut slope is located outside right of way (RoW), land development of the said area is often conducted by private parties after the opening of highways. A catchment area or flow passage direction, which was planned in a prior construction stage, may change by the development. For this reason, it is necessary to pay attention to the up-to-date status of land development, drainage channel, and catchment area on a daily basis in a maintenance stage.

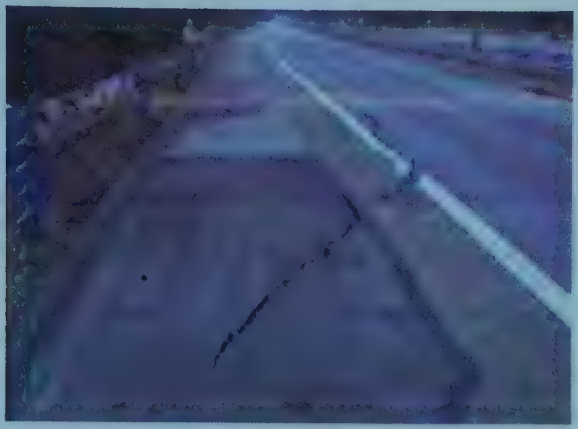
(2) Embankment

The following points should be taken into account for inspection of the embankment.

- Vegetation growth which prefers moist and wet places
- Gully erosion of embankment slope
- Circle shape crack on pavement surface (as shown in Figure 5-22)
- Depression of guard fence or guard cable (as shown in Figure 5-23)
- Unevenness of curb
- Cracks of embankment shoulder
- Heaving

Continuous cracks, shown in Figure 5-22, imply a high possibility of slip surface beneath the embankment body as well as the failure of drainage systems.

The newly constructed embankment is typically susceptible to settling, depending on the ground condition, by which drainage structure and slope protection structure constructed on such location is affected. Erosion of the backside or side of the structure may occur. Therefore, inspection should be carefully conducted for a newly constructed embankment, including initial inspection and inspection just after rainfall or show melting season. Figure 5-24 shows important points of inspection for the embankment structure.



[16]

Figure 5-22: Circle Shaped Cracks on Pavement Surface

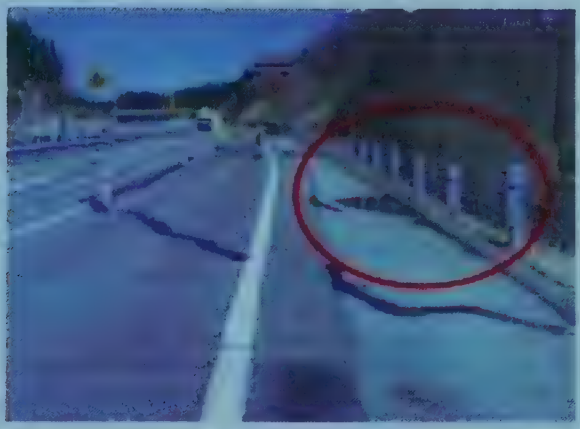


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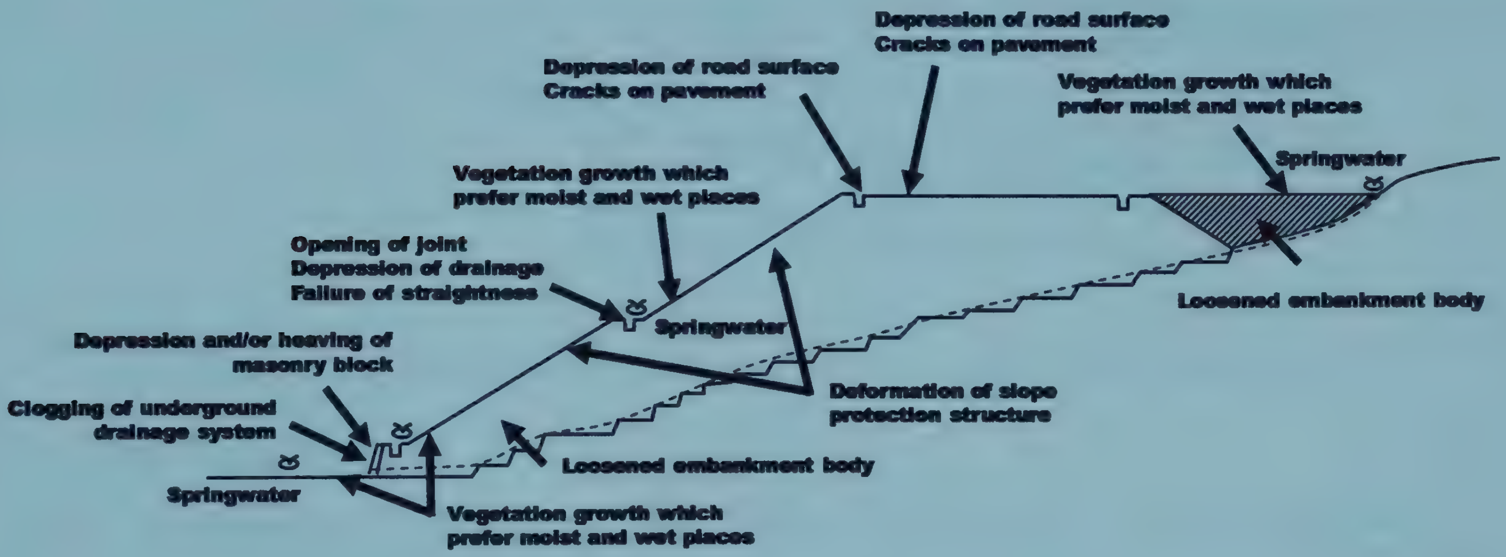
Figure 5-23: Depression of Guard Cable

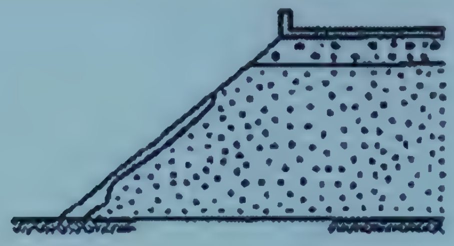

Depression of road surface
Cracks on pavement
Depression of road surface
Cracks on pavement
Vegetation growth which prefer moist and wet places
Springwater
Vegetation growth which prefer moist and wet places
Opening of joint
Depression of drainage
Failure of straightness
Springwater
Loosened embankment body
Depression and/or heaving of masonry block
Clogging of underground drainage system
Deformation of slope protection structure
Loosened embankment body
Springwater
Vegetation growth which prefer moist and wet places

[16]

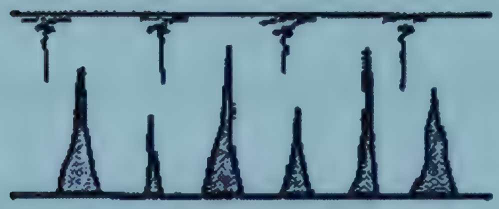
Figure 5-24: Important Points of Inspection for Cut Slope

- Slope Erosion

On a slope consisting of sandy or silty soil, gully erosion sometimes grows by flow-down of surface water. Moreover, erosion may occur when small drainage water is insufficient. Once erosion occurs, surface water flows mainly on such an area afterward, which may lead to further expansion of erosion and even slope collapse.



Cross section



Plan view

[16]

Figure 5-25: Diagram of Gully Erosion

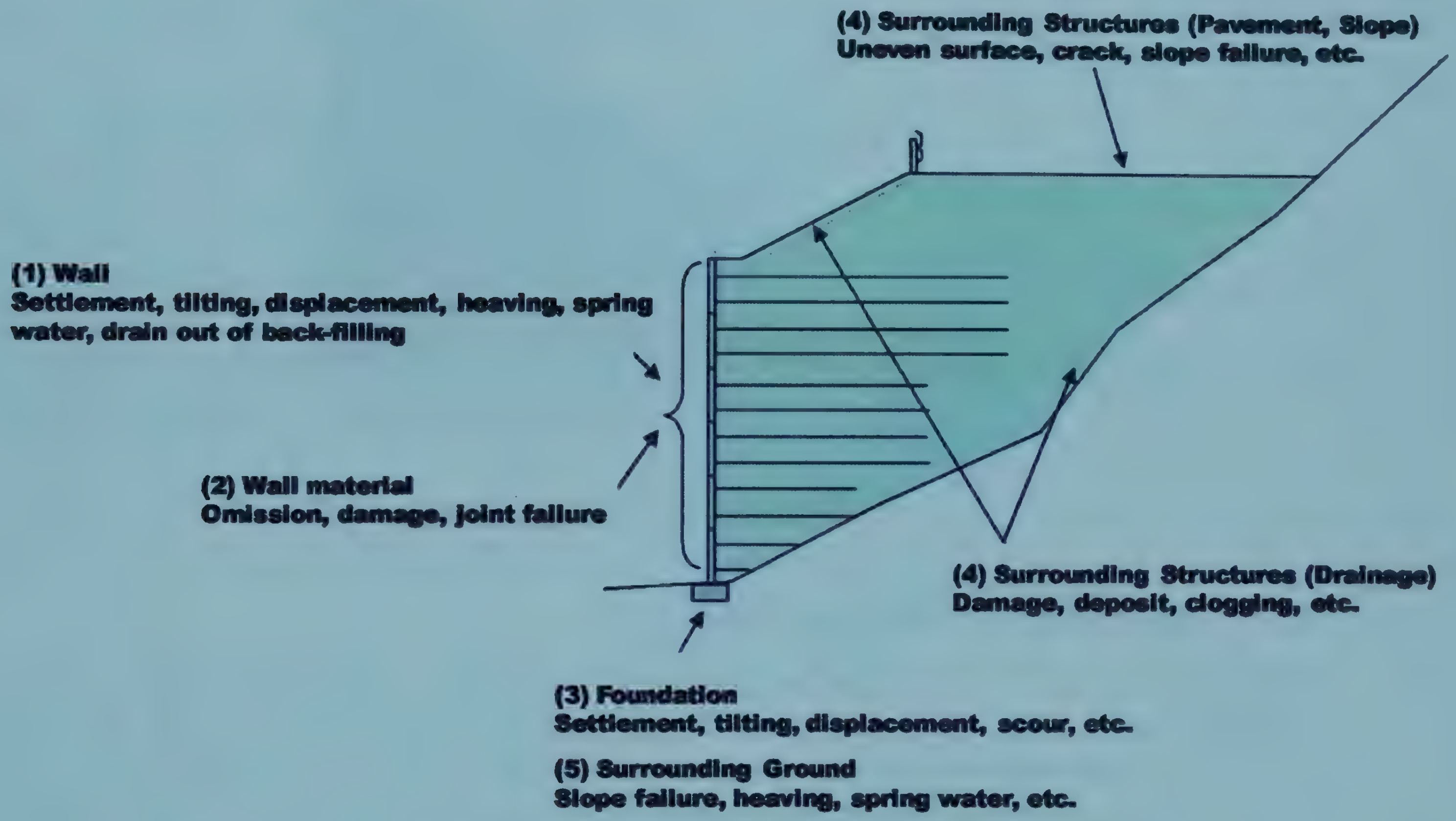
(3) Block Masonry Retaining Wall

Drain holes are installed on sealed protection work, such as concrete spraying, block masonry, which ensure to drain water smoothly and minimize the increase of water pressure. However, grass may grow on a drain hole of an old slope. Past experience shows that a drain hole which drains more water tends to have more grasses. In order to prevent any damage or deformation of such slope, it is preferable to remove grasses promptly. A location where the soil is accumulated around a drain hole after rainfall may imply that soil on the back of slope protection possibly drains away with 1drainage water. On this account, it is necessary to check whether there is a cavity on these spots by hammering the test. Where cavity is detected, it requires special attention, for instance, filling by air mortar and so on.

5.4 Inspection of Reinforced Earth

It is essential to understand the characteristics of reinforced earth for its inspection. In particular, deformation or damage of exterior wall does not necessarily mean instability of whole reinforced earth. Therefore, it is necessary to conduct comprehensive judgement, taking into account surrounding structures and conditions (e.g. main lanes, service roads).

Moreover, it needs special attention to the corrosive environment, since reinforced earth is typically equipped with metal products and thin concrete panels as reinforcing material and wall, respectively. Figure 5-26 shows important points of inspection for reinforced earth structures.


(4) Surrounding Structures (Pavement, Slope)
Uneven surface, crack, slope failure, etc.
(1) Wall
Settlement, tilting, displacement, heaving, spring water, drain out of back-filling
(2) Wall material
Omission, damage, joint failure
(4) Surrounding Structures (Drainage)
Damage, deposit, clogging, etc.
(3) Foundation
Settlement, tilting, displacement, scour, etc.
(5) Surrounding Ground
Slope failure, heaving, spring water, etc.

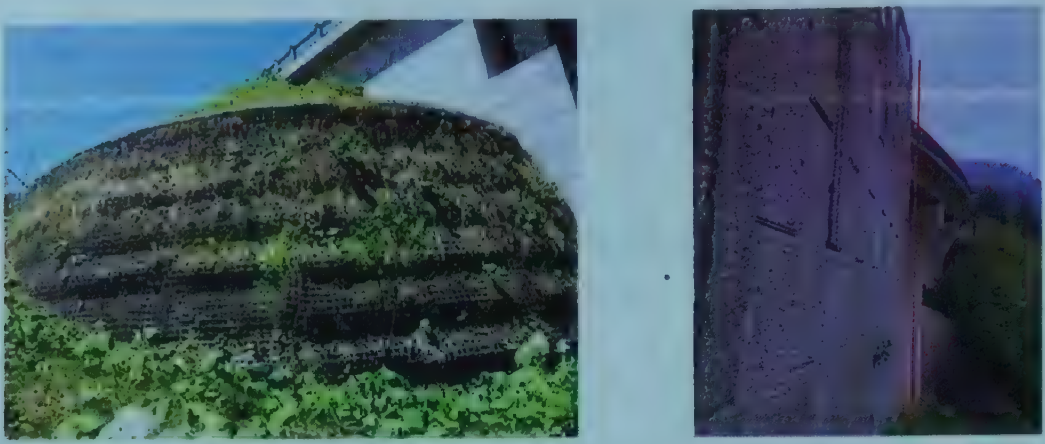
[16]

Figure 5-26: Important Points of Inspection for Reinforced Earth

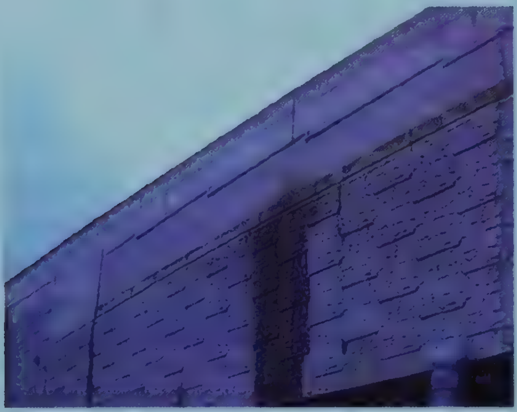
1) Deformation of Wall

Tilting, settlement, displacement, and heaving of the wall are typical deformation of walls of reinforced earth. If there is a joint opening between an adjacent structure, back-filling may run off when an earthquake hits the structure. Continuous monitoring is an effective method to observe those symptoms.

Furthermore, a large volume of spring water from the wall joint, clogging or damage of drain pipe/subsurface drainage system can increase groundwater level of back-filling behind the wall. Inspectors shall pay attention to these phenomena since they accelerate the deformation of a reinforced wall. Figure 5-27 shows the typical deformation of the wall of reinforced earth.



(a) Heaving of Wall (b) Tilting of Wall



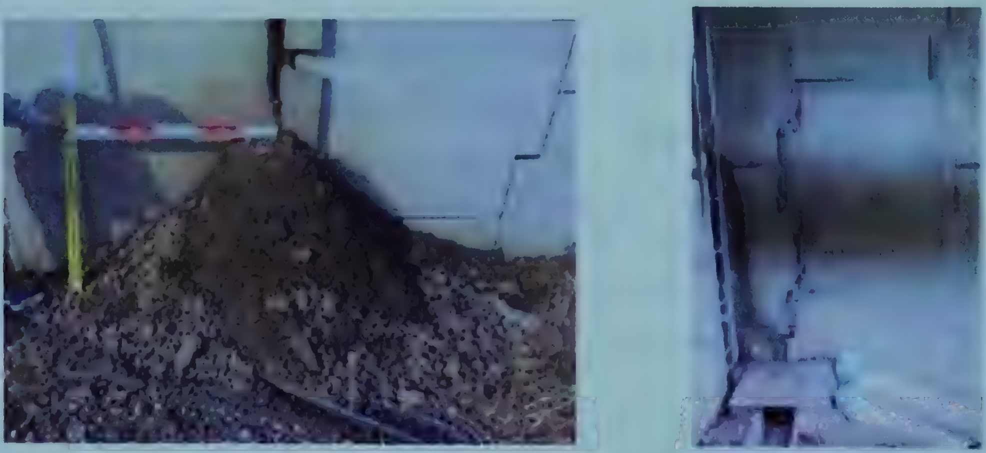
(c) Spring water from wall joint

[16]

Figure 5-27: Deformation of Wall

2) Deformation of Wall Material

Deformation of wall material includes omission, damage, crack, joint opening, displacement, etc. If these phenomena progress, back-filling may be washed away, leading to the collapse of the reinforced wall. Hence, inspectors shall pay attention to the said phenomena. Figure 5-28 shows the typical deformation of wall material.



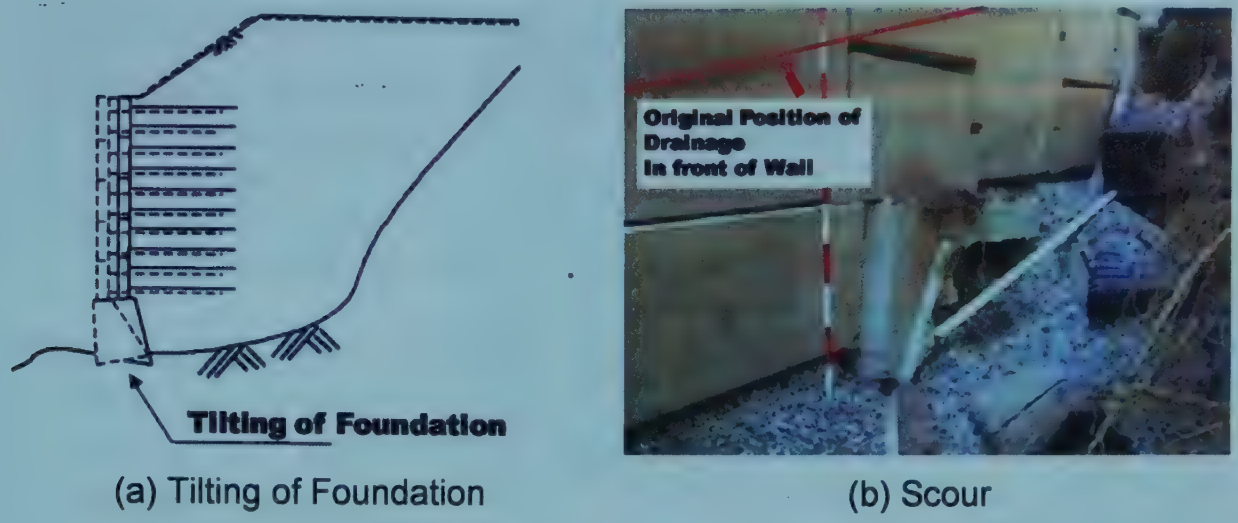
(a) Washout of Back-Filling (b) Abnormal Joint

[16]

Figure 5-28: Deformation of Wall Material

3) Deformation of Foundation

Settlement, tilting, displacement of wall foundation is typical deformation. Moreover, scour of foundation may lead to failure of reinforced earth due to washout of back-filling material.


Tilting of Foundation
Original Position of Drainage in front of Wall

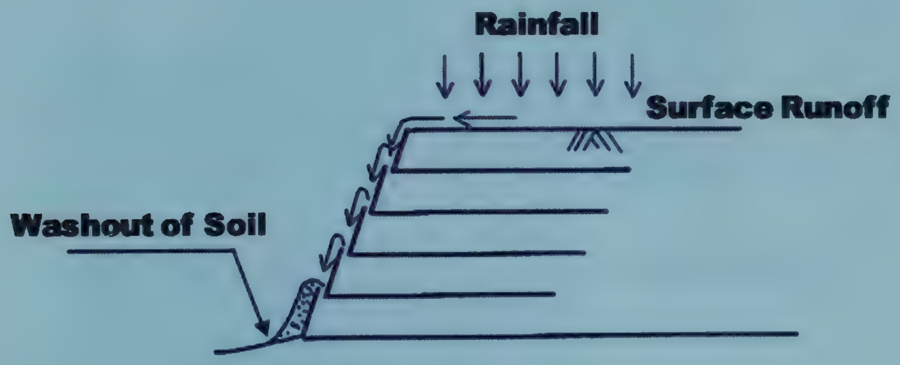
(a) Tilting of Foundation (b) Scour

[16]

Figure 5-29: Deformation of Foundation

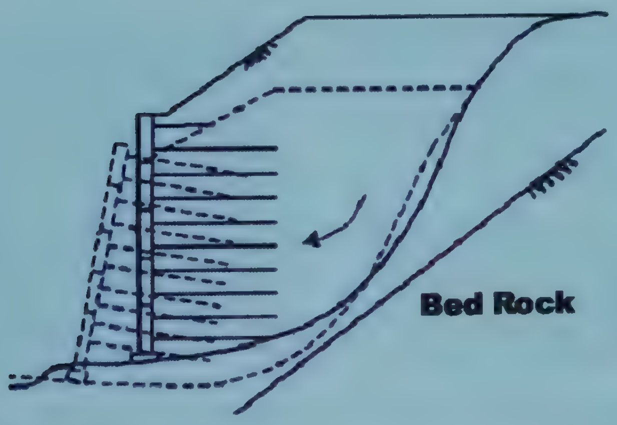
4) Displacement or Deformation of Surrounding Ground

Inspection on surrounding structure and slopes provide important clues to identify deformation of reinforced earth and thus to prevent large-scale failure of the structure. Displacement or heaving of the surrounding ground, deformation of the drainage system are examples. If necessary, field observation should be done to monitor the status and progress of deformation. Figure 5-30 and Figure 5-31 show images of deformation by rainfall and by a landslide, respectively.


Rainfall
Surface Runoff
Washout of Soil

[16]

Figure 5-30: Deformation by Rainfall



[16]

Figure 5-31: Deformation by Landslide

5.5 Inspection of Drainage System

In general, a drainage channel works as a line or group of systems by collecting surface water flowing on the slope. Good performance of drainage system is guaranteed by the good condition of all these systems, which shall be realized by good planning, design, construction, and maintenance. For planning, design, and construction parts, IRC:SP:73 and Guidelines for Planning and Surveying shall be referred.

Past experience shows that defect of the road surface or slope failure is often triggered by failure or damage of the drainage system. In other words, one of the major causes of slope collapse is a defect in the drainage structure. If any defect happens, however, water that has been collected may mainly flow from a defected area into the ground (or inside an embankment), which leads to destabilization of earth structures. Therefore, it is critical to inspect on-site conditions in a proper way and identify the abnormal situation as early as possible. For example, the inspector shall pay attention to changing points of gradient, such as around the catch basin, and check if there is any trace of abnormal water flow and/or scour around drainage. In case leakage from masonry joint, scour around channel, or clogged/stagnant channel is detected, immediate repair is crucial as soon as possible.

Figure 5-32 shows a significant inflow of drainage water from cascade drain into catch basin on a berm, which is causing scour around the drainage. Moreover, it is recommended to inspect not only for drainage systems themselves but also for surrounding areas to avoid the bonding of water.

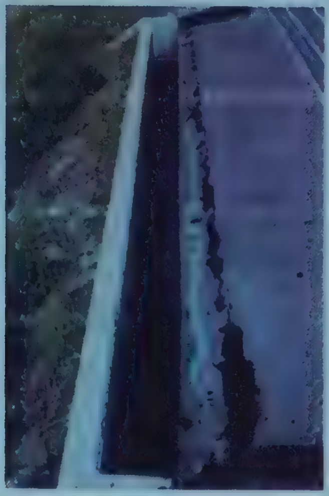
[16]

Figure 5-32: Hydraulic Jump of Drainage

5.5.1 Roadside Drainage System

1) Failure of Drainage System Body

Cracks, depression, and settlement of drainage, as well as tilting of the side wall of drainage, may lead to infiltration of rainwater into earth structures, resulting in defects of the road surface. Moreover, infiltration of drainage water sometimes causes leakage water into transverse structures, such as box culverts. Hence, an inspection for the drainage system is recommended if leakage water is observed in a box culvert.

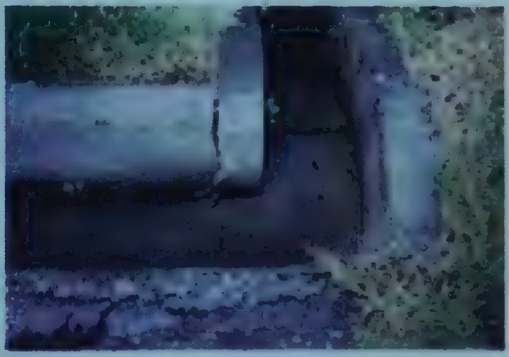


[16]

Figure 5-33: Failure of Drainage System Body

2) Failure of connection

Failure of connection between catch basin and drainage, especially joint opening, may lead to rainwater infiltration into earth structure, causing failure of the road surface. Figure 5-34 shows join opening due to settlement of cascade drain.

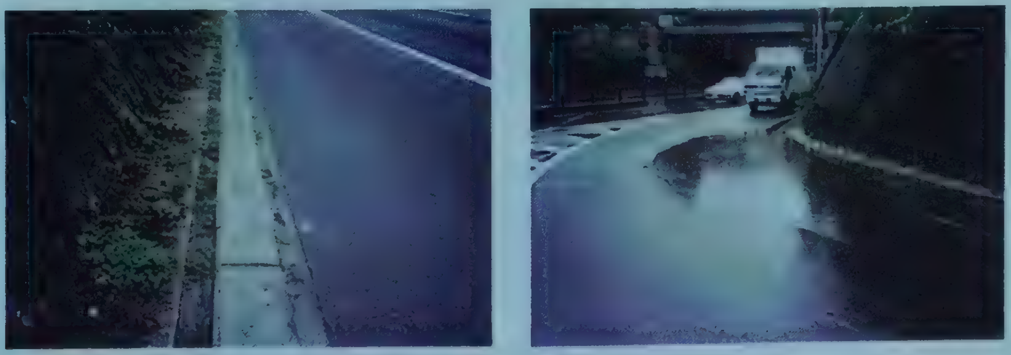


[16]

Figure 5-34: Joint Opening of Drainage

3) Deposit of trash and sand

Deposit of trash and sand may cause ponding on road surface due to failed drainage function, posing danger to traffic safety.



[16]

Figure 5-35: Poor Drainage Capacity due to Deposited Dust and Soil

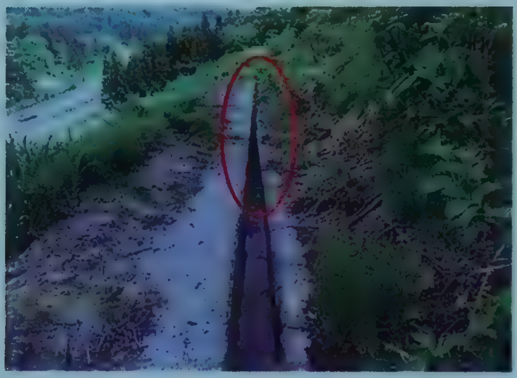
5.5.2 Slope drainage system

1) Slope drainage

Crack, settlement, or depression of slope drain, as well as tilting of the side wall of drain, allows rainwater infiltration into the slope, which may cause significant damage to the slope, triggering slope failure. Moreover, settlement of embankment or accumulation of snow leads to depression of drainage structure or opening of joint, causing overflow/leakage of drained water, which also critically damages slope. Basically, rainwater infiltration from the slope shoulder is a major driving factor of slope deformation, which mechanism shall be kept in mind.

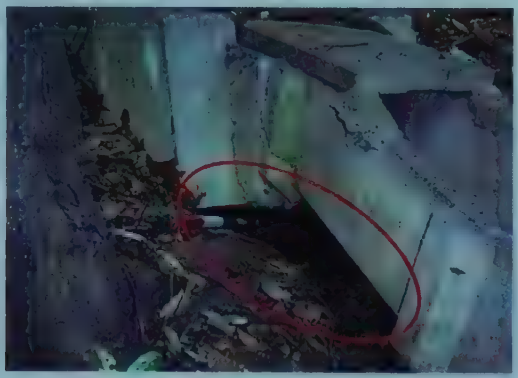
The lid of the catch basin aims to prevent overflow of drained water and trap ~~of~~ weed or trash deposits into the drainage system. In case a failure of lid causes significant overflow or decreased drainage capacity, it may result in scour around the catch basin. Inspection of the catch basin shall be done by confirming conditions of the side wall and bottom plate, as well as surrounding ground conditions.

Figure 5-36 shows a symptom of deformation of slope drainage on a berm, which may be caused by the deformation of the slope. A detailed survey on a concerning slope and its surroundings is recommended. Figure 5-37 shows a symptom of scour around a catch basin on a slope. It is recommended to inspect the soundness of connection between catch basin and drainage, as well as the condition of overflow during rainfall.



[16]

Figure 5-36: Deformation of Slope Drainage on Berm

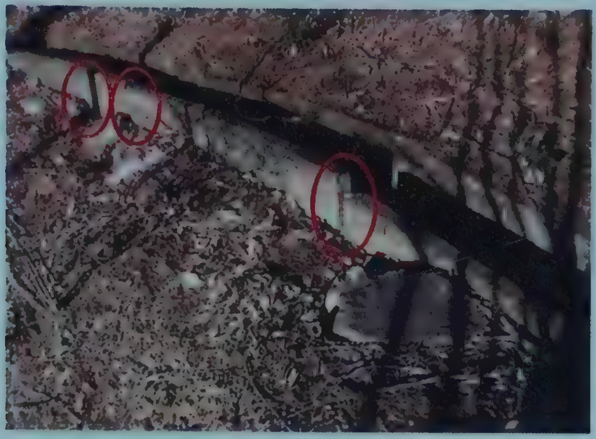


[16]

Figure 5-37: Scour Around Catch Basin

2) Connection failure

A failure of the joint opening of connection between drainage and catch basin (or between drainage and drainage) causes leakage of water, triggering slope failure. In particular, cascade drain, in which drained water velocity is high, or bending location is more likely to induce overflow or jump, causing significant damage to the slope.



[16]

Figure 5-38: Failure of Connection between Drainage on Slope Shoulder

3) Deposit of trash or sand

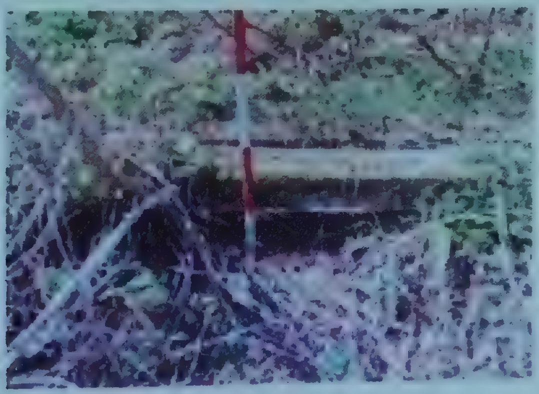
Deposit of trash or sand leads to ponding of drained water during/after rainfall. In particular, a location, where is more likely to capture water, including the shoulder of the cut slope, berm, or around the water stream, is more susceptible to rainwater infiltration into the slope with overflow or hydraulic jump. Likewise, a deposit of trash or sand in a catch basin may clog a drainage pipe in a downstream direction. Inspectors shall pay attention to these points when conducting the inspection.

[16]

Figure 5-39: Deposit of Fallen Leaves

4) Scour beneath seal concrete

Seal concrete around drainage on berm aims to prevent scour and deposit of weed into the drainage system. Crack, depression, or heaving of seal concrete induces scour or gully erosion, leading to slope failure as a result.

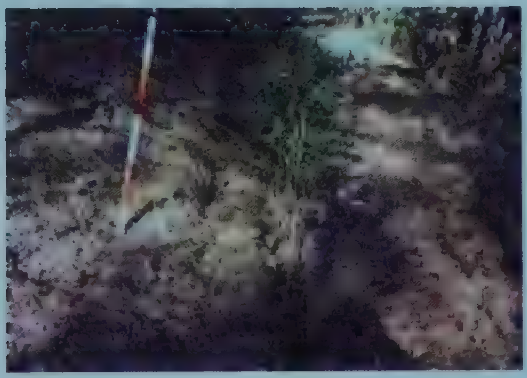


[16]

Figure 5-40: Scour under Drainage

5) Weed growth

Weed growth inside drainage systems, including berm drain, cascade drain, or catch basin, may hinder the original function of draining water out from a slope. As a result, it may cause significant damage to a concerned slope. Inspectors shall confirm if there is scour around the drainage system, gully erosion, and so forth.



[16]

Figure 5-41: Failure of Connection between Drainage on Slope Shoulder

5.6 Inspection of Slope Protection Work

In general, close types of slope protection works, such as mortar spray shotcrete and concrete block masonry retaining walls, have been constructed to prevent weathering, erosion, and collapse of a slope. This is especially done for a type of soft rock with multiple cracks which is susceptible to weathering. In case of development of many cracks or growth of unintended vegetation, rainwater infiltrates into slope ground through open cracks, which enhances weathering process. Spring water may also wash away weathered soil, resulting in cavity formation below a slope protection work. It shall be kept in mind that large-scale slope failure may occur unless such slope is identified at an early stage by proper inspection.

5.6.1 Precast Concrete Crib Work and Cast-in-situ Concrete Crib Work

1) Crack and spalling

Cracks and spalling of concrete crib work suggest the possibility of deformation of slope ground or upper slope; therefore, comprehensive judgement should be done by considering condition/damage of a concerned whole slope, topography, and geology. In particular, inspectors shall pay due attention to horizontal cracks, since such cracks are often triggered by deformation of slope ground.

2) Loosening, heaving, and depression

The phenomenon of loosening, heaving, or depression should be judged by not only focusing on a spot with the phenomenon but also observing a whole condition of a concerned slope.

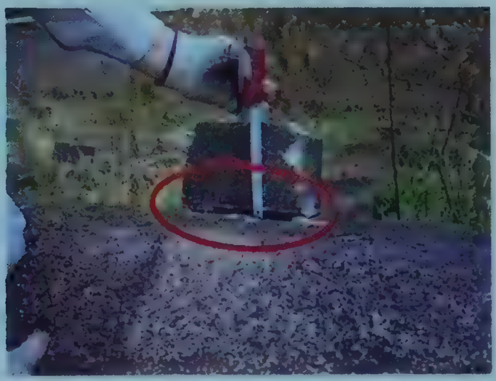
3) Drainage failure

Drainage failures of rainwater or spring water sometimes cause a problem with a whole slope. Inspectors should pay attention to the change of water volume and transparency. It should also be inspected whether water is ponding inside the crib frame and horizontal drainage boring is clogged or not.

5.6.2 Rock Bolts and Ground Anchor

Condition of rock bolts and ground anchor cannot be visually inspected except for bolt/ anchor head because of the nature of the structures. For this reason, inspectors should observe the condition of a head together with a concerned slope. Figure 5-42 and Figure 5-43 show spalling of anchor head and projection of rock bolts, respectively. These phenomena imply the possibility of deep-seated landslide, which slip surface is deeper than the entire length of rock bolt or ground anchor.

Figure 5-44 shows cracks developed on the surface of cast-in-situ concrete crib work, which suggests increased bending stress on the crib work. Figure 5-45 shows continuous cracks on the surface of concrete spray shotcrete, which implies punching share stress put on the structure. Both cases imply the possibility of greater stress than design conditions developed on the slope structures. Figure 5-46 shows the warping of a head plate of a rock bolt. In this case, detailed investigation and consideration of countermeasures become necessary together with results of relevant inspections.



[16]

Figure 5-42: Spalling of Anchor Head

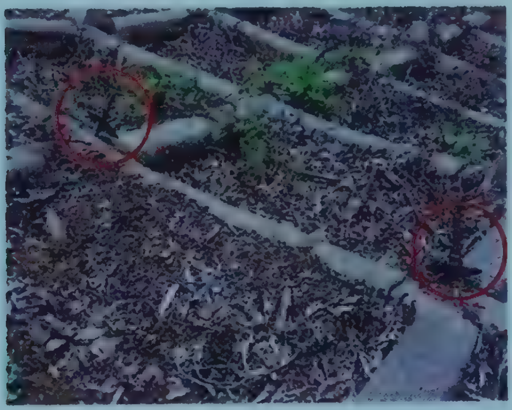


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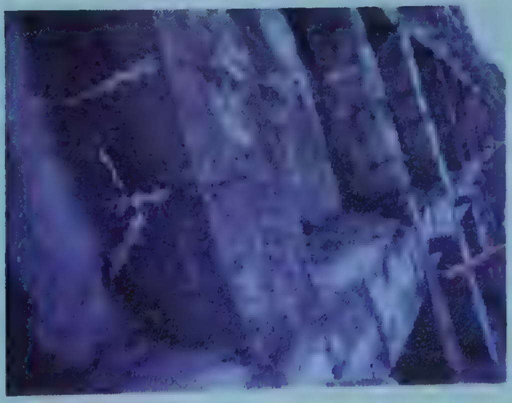
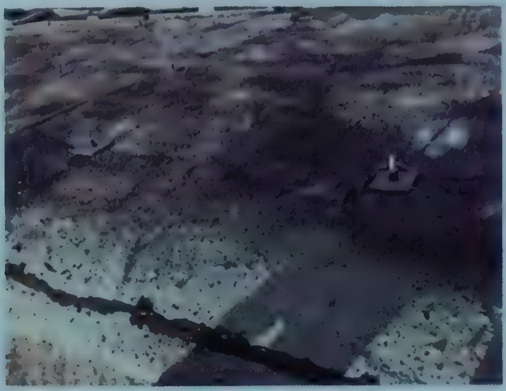
Figure 5-43: Projection of Rock Bolts



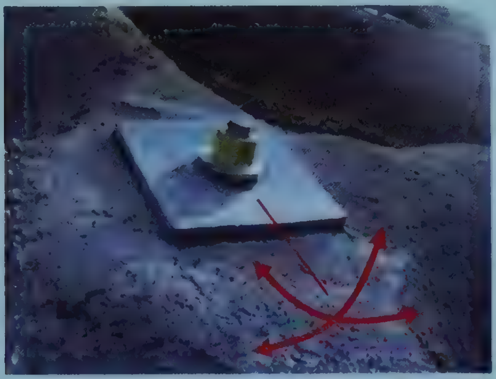
[16]

Figure 5-44: Cracks on Crib Work



[16]

Figure 5-45: Cracks on Concrete Spray



[16]

Figure 5-46: Warping of Head Plate of Rock Bolt

5.6.3 Mortar Spray Shotcrete and Concrete Spray Shotcrete

1) Crack and spalling

Shotcrete sometimes has a symptom of aggregate separation or spalling due to drying shrinkage, freezing, melting, or repetition of the drying and moisture process. In particular, a crack or spalling around the joint is more likely to cause a fallen piece of concrete to the road surface, which poses a danger to passing pedestrians and vehicles. Moreover, increasing width or number of cracks implies the possibility of slope failure below shotcrete; therefore, detailed investigation and study of countermeasure should be performed in such a case.

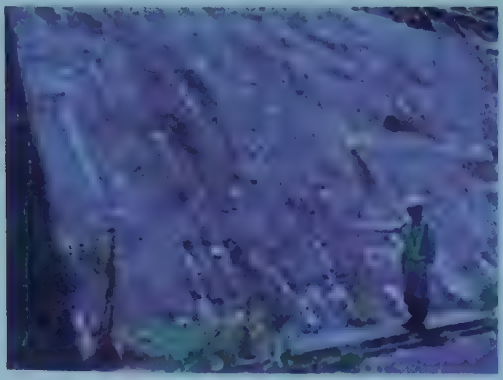
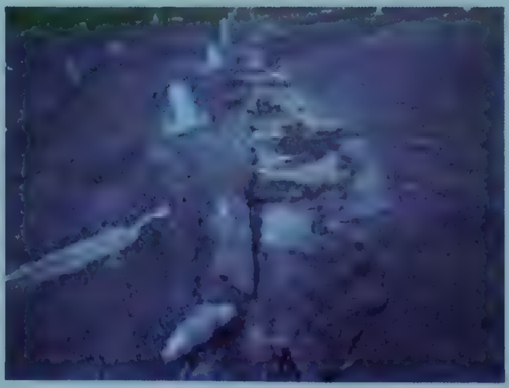


Figure 5-47: Alligator Crack

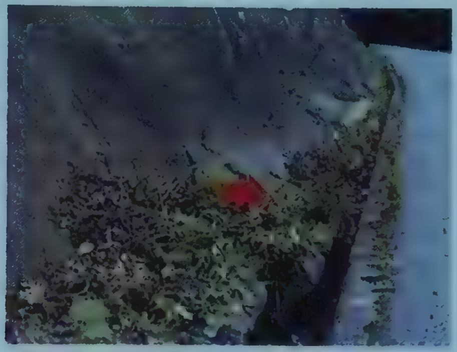


[16]

Figure 5-48: Spalling

2) Heaving, push-out, and displacement at joint

Shotcrete typically does not have a foundation with its structure, because it is so designed and constructed to be closely contacted with the ground slope below the shotcrete. However, a push-out phenomenon of toe sometimes happens due to aging and weakened slope ground. In particular, due attention is necessary for a type of soil which is susceptible to frost heaving in a cold region, because anchor pins of shotcrete are sometimes dropped out with slope ground becoming muddy in snow-melting season, which may trigger a slope failure. Moreover, a symptom of heaving or displacement at a joint is sometimes caused by failure of slope ground behind shotcrete, which situation should be comprehensively judged in consideration of a condition of a whole slope, topography, geology, etc. Figure 5-49 shows an example of a push-out phenomenon of a slope toe covered by shotcrete. As can be seen in the figure, the side wall of drainage is tilting by a push-out phenomenon. This case indicates the possibility of a large-scale deep-seated landslide; therefore, a series of inspections for a concerned slope becomes necessary.



[16]

Figure 5-49: Push-out Phenomenon of Slope Toe

3) Cavity formation

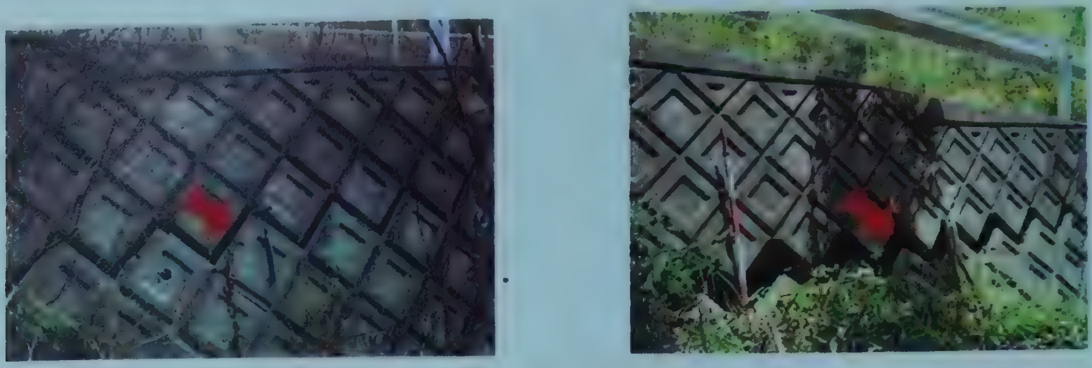
While it is not easy to identify the existence or location of cavity formation by visual inspection, it can be estimated by an understanding of the position of cracks and intrusion of unintended vegetation. Based on such results, hammering inspection is often an effective method to identify the existence or location of the cavity. In case a cavity is large and poses a risk of slope failure, a detailed investigation and study of countermeasures shall be conducted.

5.6.4 Stone Masonry Retaining Wall and Concrete Block Masonry Retaining Wall

1) Crack, loosening, and heaving

In case a limited number of non-progressive cracks are formed on a stone masonry /concrete block retaining wall, past experience shows such a structure is typically considered stable in many cases. However, if the deformation of slope ground causes such a phenomenon or if directions of cracks on a wall are aligned with the direction of rock joint of dip slope, faulting, or fracture zone, it may lead to large-scale slope failure. Similarly, past experience shows that the horizontal direction of cracks is sometimes an indication of large-scale slope failure, which needs due attention by inspectors. Figure 5-50 shows a symptom of the joint opening of a concrete block masonry constructed in a landslide zone (see a small red arrow in the figure). Due to the sliding of the toe of landslide mass, the opening expanded (See Figure 5-50(b)) eight years later from the picture of Figure 5-50(a). Figure 5-51(a) shows a phenomenon of spalling of masonry block, which may progress to the case in Figure 5-51(b), in which a part of blocks are fallen down with intrusion of unintended vegetation.

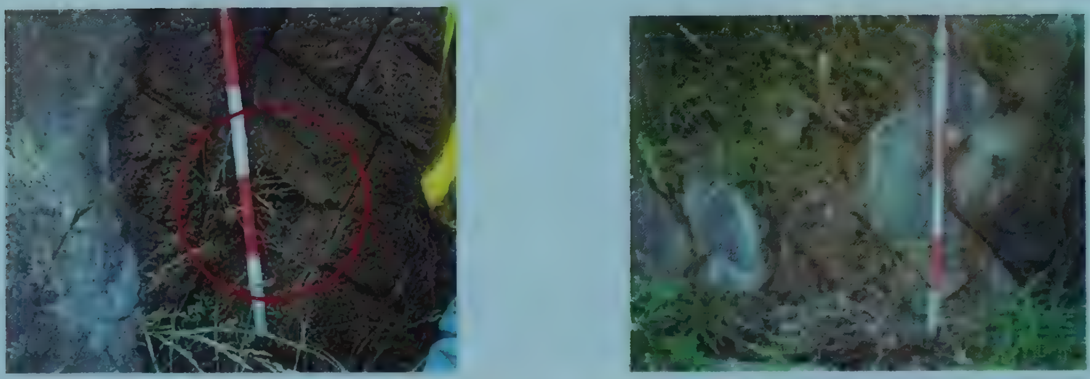
It should be kept in mind that deformation of slope causes the damage of slope protection work, which further causes deformation of a slope, and vice versa. In this sense, a road administrator and inspectors shall pay close attention to the fact that maintaining a good condition of ground slope and slope protection work is mutually related to each other.



(a)Joint Opening (b) Eight Years Later from the Case of (a)

[16]

Figure 5-50: Block Masonry in Landslide Area



(a)Spalling (b) Progressed Condition from the Case of (a)

[16]

Figure 5-51: Block Masonry on Landslide Area

2) Depression, displacement, and tilting

Progressed depression, displacement, and/or tilting of masonry work may cause depression and cracks of a slope behind a masonry wall. This phenomenon may result in a tilted lighting pole or an unstable road sign foundation, which poses a threat to passing pedestrians and vehicles. Moreover, excessive deformation of a masonry wall tends to have a negative effect on a slope above the wall, which may trigger a slope failure or failure of the road structure. Inspectors shall pay due to attention to these points.

3) Failure of joint

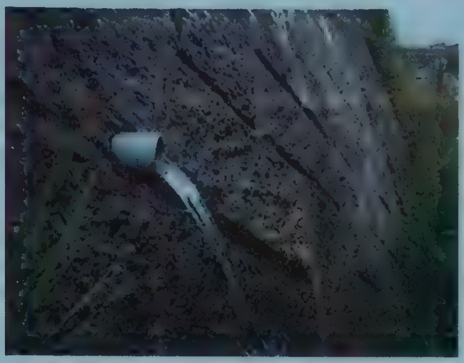
Localized small joint openings or displacement of masonry work does not typically mean unstable slope, in case such an abnormality is not progressing. However, a judgement should be comprehensively done by paying attention to a concerned whole slope around a masonry wall, since there is still the possibility of deformation of slope ground behind a masonry wall.

4) Scour

Scour around a masonry foundation may cause tilting or sliding of a wall. Thus, inspectors shall pay attention to any trace of scour around the wall foundation.

5) Drainage and spring water

Figure 5-52 shows an example of spring water observed at a drainage hole of the masonry wall. This phenomenon implies increased groundwater level; therefore countermeasures, such as installation of horizontal drainage boring or additional drainage holes, shall be studied.

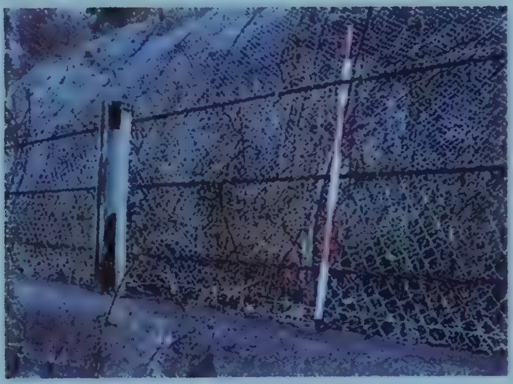


[16]

Figure 5-52: Spring Water from Drainage Hole of Masonry Wall

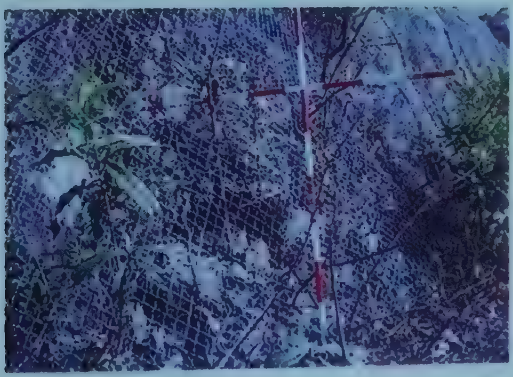
5.6.5 Rock Fall Protection Net and Rock Fall Protection Fence

During a course of an inspection of rock fall protection net/fence, it is necessary to check if each structure and member keeps functioning, considering the future necessity of repair works. Figure 5-53 shows broken net and corroded cable of rock fall prevention fence. In case the natural ground is strongly acidic, it tends to enhance the corrosion process, to which special attention shall be paid. As a matter of course, a broken or corroded part of the fence cannot prevent fallen rocks; therefore an immediate countermeasure work is deemed necessary. Figure 5-54 shows a deposit of fallen rocks inside the pocket of a rockfall prevention net, which implies the possibility of falling off the further bigger size of rocks in the near future. It is therefore strongly recommended that a detailed investigation is to be conducted over a potential source of such a location including the upper slope and that a deposit of rocks is to be removed at the earliest possible time.



[16]

Figure 5-53: Broken Net and Corroded Cable



[16]

Figure 5-54: Deposit of Fallen Rock

5.7 Inspection of Mountain Tunnel

A comprehensive understanding of symptoms and phenomena is the first step to finding the abnormality of a mountain tunnel in the early stage and determining driving factors. A tunnel has various forms of defects, including a crack or a deformation on a concrete lining, portal, and/or pavement surface, as well as flaking, spalling, leakage of groundwater, deformation of surrounding mountain mass. This chapter aims to outline symptoms and phenomena according to driving factors. Readers are also expected to refer to the maintenance chapter of IRC:SP:91, where necessary.

5.7.1 Classification of Defects

Definition of defects includes initial defects during construction, damage, and aging failure. It should be kept in mind that defects of a mountain tunnel do not happen only on a lining concrete. Table 5-8 shows the typical classification of deformation of a mountain tunnel.

Table 5-8: Classification of Defects of Mountain Tunnel

Target structure	Symptom	
Lining concrete	Crack	Crack
		Joint gap
		Step surface
		Opening due to cold joint
	Deformation, displacement, depression, tilting of ide wall	
	Aging, spalling, stripping, flaking	
	Water leakage, icicle, ice on a side wall, deposit of soil, efflorescence	
Road surface	Crack/deformation of the side ditch	
	Heaving/depression/cracks of road surface, shoulder, or inspection gallery	
	Deposited mud/soil, water ponding, ice surface	
Tunnel portal	Crack	
	Step surface	
	Tilting, depression, displacement	

[16]

5.7.2 Driving Factors

Driving factors of tunnel defects are largely classified into external factors and internal factors. Additionally, the defects are classified into natural factors and human factors. Table 5-9 shows this concept of classification.

Table 5-9: Classification of Driving Factors

		Natural factors	Human factors
External factors	External force	Topography: unsymmetrical pressure, slope creep, landslide Geology: plastic compression, losing pressure, ground settlement, poor bearing capacity Groundwater: water pressure, frost heaving pressure Others: earthquake, crustal movement	Neighboring construction
	Surrounding condition	Aging: weathering, neutralization, material deterioration Groundwater: leaked water, freezing damage (low temperature in winter) Others: salt damage, detrimental water	Fire
Internal factors	Material	--	Defect of the lining material
	Construction	Temperature and humidity at the time of placement of lining concrete	Prescribed quality not assured
	Design	--	A design which does not consider external factors

[16]

5.7.3 Defects on Lining Concrete

(1) Defects due to External Force

External force includes unsymmetrical pressure (incl. slope creep and landslide), plastic compression, losing pressure, water pressure, etc. Moreover, concentrated loading, insufficient bearing capacity, earthquakes are also related to the defects due to external force.

The following cases may lead to significant damage to a mountain tunnel; therefore, special attention shall be paid.

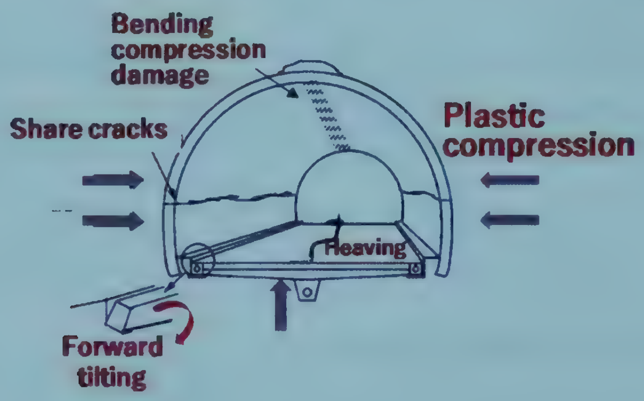
1) In case the external force is interacted due to unexpected landslide, or in case neighboring construction of embankment just above a tunnel causes a change of earth pressure on a tunnel in service, it may lead to defects of a tunnel or progress and expansion of existing defects.
2) In case of roof fall or significant deformation due to plastic compression happens during tunnel excavation work, or in case of an abnormal amount of water flow, it may lead to defects of a tunnel or progress and expansion of existing defects. These failures are often turned into challenging conditions, and therefore, due attention shall be paid.
3) In case a cavity exists behind lining concrete, a tunnel is more susceptible to an external force due to the difficulty of obtaining reaction force.
4) Failure of drainage system results in an increased level of groundwater and increased water pressure, which leads to degraded ground condition.

Furthermore, earthquakes and insufficient ground bearing capacity may trigger significant damage to a tunnel.

(2) Plastic Compression Pressure

Plastic compression pressure is placed to a tunnel, when strength of a ground mass decreases due to such as increased groundwater level, or when a creep of a ground progresses. Mudstone, shale, tuff, weathered crystalline schist, transformed volcanic rocks, serpentinite, fault fracture zone are typical types of rocks which are susceptible to plastic compression pressure.

In case a plastic compression pressure is formed in a horizontal direction, longitudinal share cracks on a side wall of a tunnel are typically present, as shown in Figure 5-55. To differentiate cracks caused by cold joint from those by plastic compression pressure, it shall be kept in mind that share cracks by plastic compression pressure are not separated by a construction joint, while cracks by cold joint are separated by a construction joint. Moreover, an increase of plastic compression pressure may lead to the uneven surface of a part of share cracks, which implies critical conditions.

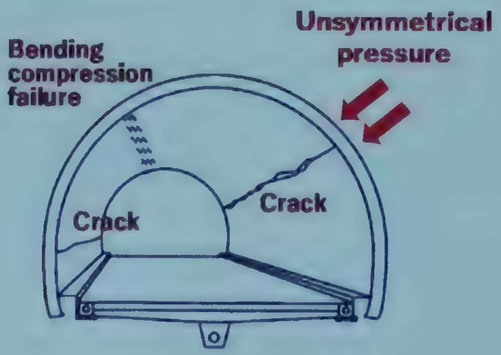


[16]

Figure 5-55: Defects due to Plastic Compression Pressure

(3) Unsymmetrical Pressure

Unsymmetrical pressure is typically formed in a place where overburden thickness is different on the left and right sides. Large-scale unsymmetrical pressure is triggered by a landslide. Moreover, unsymmetrical pressure tends to be significant if a dip slope exists or a weak layer is sandwiched in the overburden. Deformation happens in the form of continuous longitudinal cracks in the shoulder of the lining, as shown in Figure 5-56.

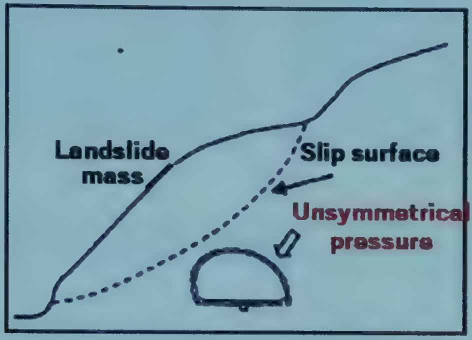


[16]

Figure 5-56: Defects due to Unsymmetrical Pressure

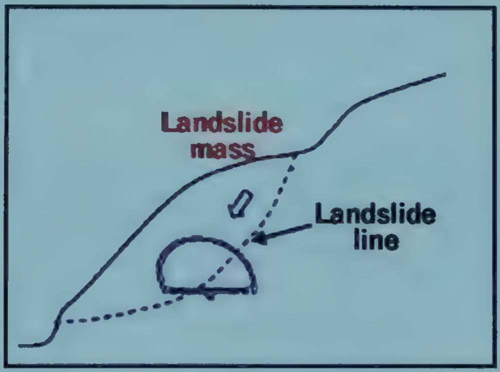
(4) Landslide

There are largely two cases of defects caused by the landslide. The first case is where a tunnel tube is under landslide mass or slip surface, as shown in Figure 5-57. In this case, deformation happens just the same as unsymmetrical pressure, as explained above. The second case, on the other hand, is where the tunnel tube crosses the slip surface, as shown in Figure 5-58. In this case, complex deformation happens shown in Figure 5-58. In the place where the slip surface crosses a tunnel tube, the tunnel deforms as if it is twisted, leading to the development of diagonal cracks.


Landslide mass
Slip surface
Unsymmetrical pressure

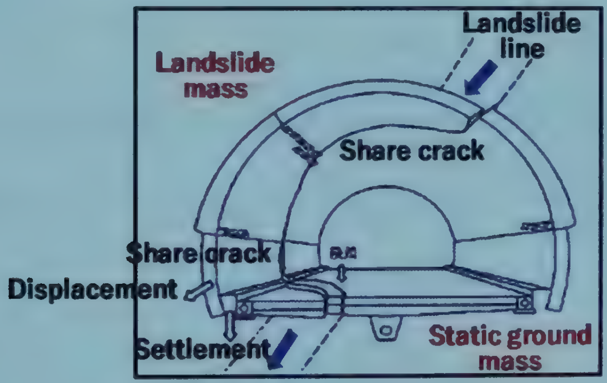
[16]

Figure 5-57: In case of Tunnel is under Slip Surface of Landslide


Landslide mass
Landslide line

[16]

Figure 5-58: In case Tunnel Tube Crosses Slip Surface of Landslide

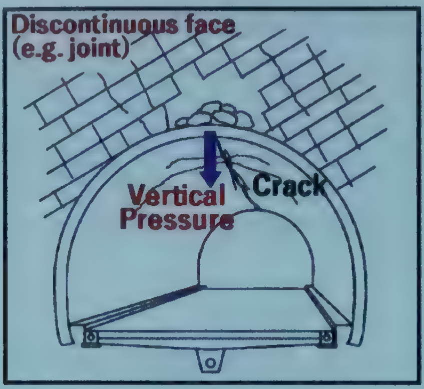

Landslide line
Landslide mass
Share crack
Share crack
Displacement
Settlement
Static ground mass

[16]

Figure 5-59: Defects of Tunnel which Crosses Slip Surface of Landslide

(5) Vertical Pressure due to Loosened Ground

In a place where a cavity exists behind the crown part of a tunnel, uneven stress and bending force are generated on tunnel support, because earth pressure is not acted on tunnel support evenly. This symptom is typically triggered by the cases when the opening of discontinued rock plane is weathered or aging due to intrusion of groundwater and air or when a part of rock masses are separated from a ground mass and fallen down on a lining concrete of a tunnel crown. Deformation happens in the form of longitudinal cracks at the top of the crown, as shown in Figure 5-60. If vertical pressure is increased and acted at a spot and localized area, transverse or block cracks appear. In the worst case, the lining collapses suddenly.

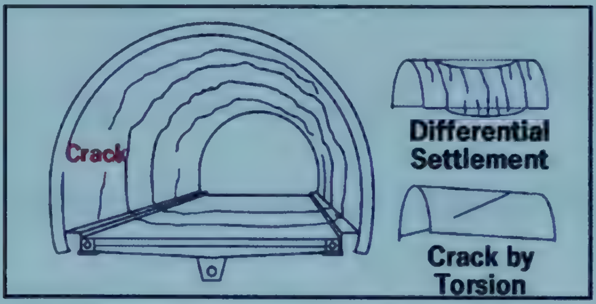

Discontinuous face (e.g. joint)
Vertical Pressure
Crack

[16]

Figure 5-60: Defects due to Vertical Pressure by Loosened Ground

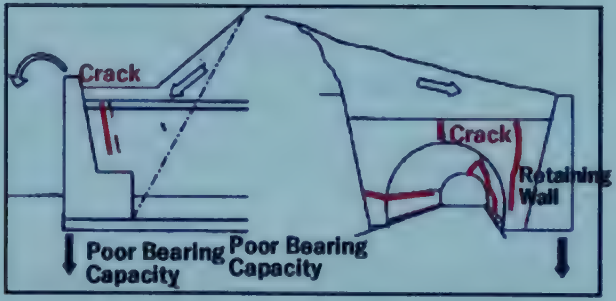
(6) Poor Bearing Capacity of Ground

If a tunnel does not have a structure of invert, and uneven settlement happens, transverse cracks in round slice shape appear in the lining, as shown in Figure 5-61. In case torsional displacement happens by settlement, diagonal direction cracks may occur. Moreover, the tunnel portal area does not have the good bearing capacity, the portal or retaining wall structure is tilted, leading to the appearance of cracks, as shown in Figure 5-62. It is to be noted that this type of symptoms is more likely to occur on weathered or deteriorated soft-ground in steep terrain.


Crack
Differential Settlement
Crack by Torsion

[16]

Figure 5-61: Defects of Tunnel Tube Caused by Poor Bearing Capacity of Ground

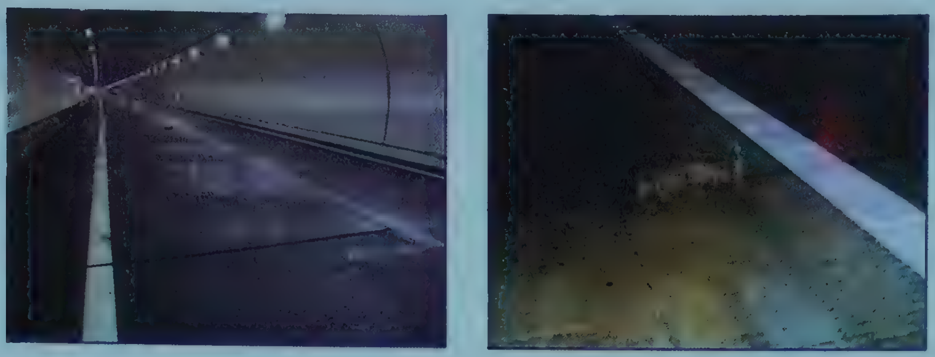

Crack
Crack
Retaining Wall
Poor Bearing Capacity
Poor Bearing Capacity

[16]

Figure 5-62: Defects of Tunnel Portal Caused by Poor Bearing Capacity of Ground

(7) Increase of Groundwater Level

In general, significant water pressure is not acted on the tunnel because groundwater is discharged from the drain system of a tunnel. However, if heavy rain continues or the drain system has some forms of troubles, groundwater level increases, and the water pressure acts on the tunnel. These conditions may lead to water logging on the road surface or water jetting from pavement joints. While water leakage itself is not very serious to tunnel lining structures, it may affect traffic safety due to ponding water on the road surface. Figure 5-63 shows an example of water ponding from leakage water due to increased groundwater levels.



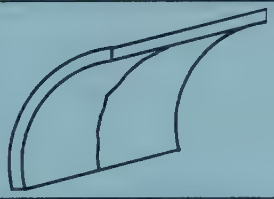
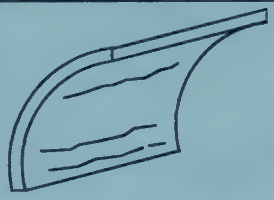
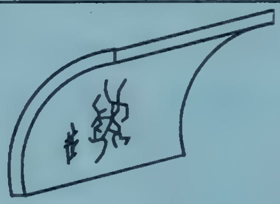
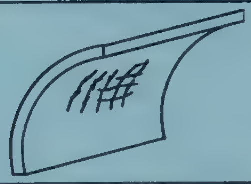
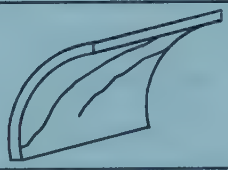
[16]

Figure 5-63: Ponding due to Increased Groundwater Level

5.7.4 Defects due to Material and Construction

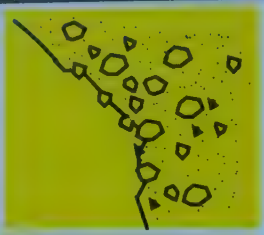
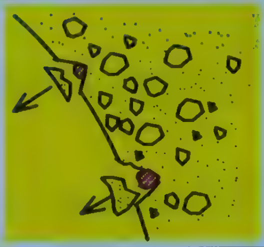
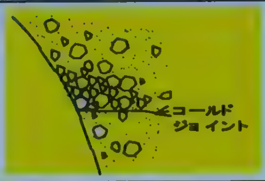
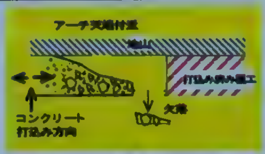
This section describes defects caused by internal factors (i.e. material and construction factors). These are the not typical damage on tunnels, basically common damage on a concrete structure, therefore this section outlines the phenomenon briefly, as shown in Table 5-10. In terms of deformation on concrete, there are mainly four types of symptoms, as shown in Table 5-11.

Table 5-10: Classification of Driving Factors

Item	Defects	Typical driving factors
(1) Transverse crack		- Bedrock confining pressure by concrete shrinkage during concrete hardening - Temperature stress - Uneven settlement
(2) Horizontal crack		- Rapid placement of concrete - Temperature stress - Early form removal - Cold joint - Bedrock confining pressure by concrete shrinkage during concrete hardening
(3) Irregular crack		- Rapid drying during initial cure - Poor aggregate - Abnormal setting of concrete - Alkali-aggregate reaction - Frost Damage - Fire inside the tunnel
(4) Line/ rectangle crack		- Steel corrosion by neutralization or internal/ external salt
(5) Diagonal crack		- Cold joint

[16]

Table 5-11: Symptoms of Defects of Lining Concrete and Driving Factors

Item	Defects	Typical driving factors
(1) Scaling		- Cold damage - Chemical damage by acid or salt
(2) Popout		- Cold damage - Poor quality of aggregate, the inclusion of detrimental mineral - Alkali-aggregate reaction
(3) Honeycomb		- Poor concrete placement (i.e. insufficient compaction, excessive compaction)
(4) Construction failure at joint	 アーチ天端付近 地山 打込み済み覆工 欠落 コンクリート 打込み方向 	- Concrete is NOT poured till span end, resulting in insufficient coverng depth of rebar and honeycomb

[16]

5.8 Inspection of Mountain Bridge

Many mountain bridges are constructed to cross river systems. In hill areas and during/after heavy rainfall, river flow tends to be very rapid, and therefore, bridge foundation and footing typically have a higher risk of scouring. As described in "Guideline for Mountain Bridge with Advanced Technology", it is essential to duly study relevant factors of scour in the planning stage and reflect it in the subsequent design stage.

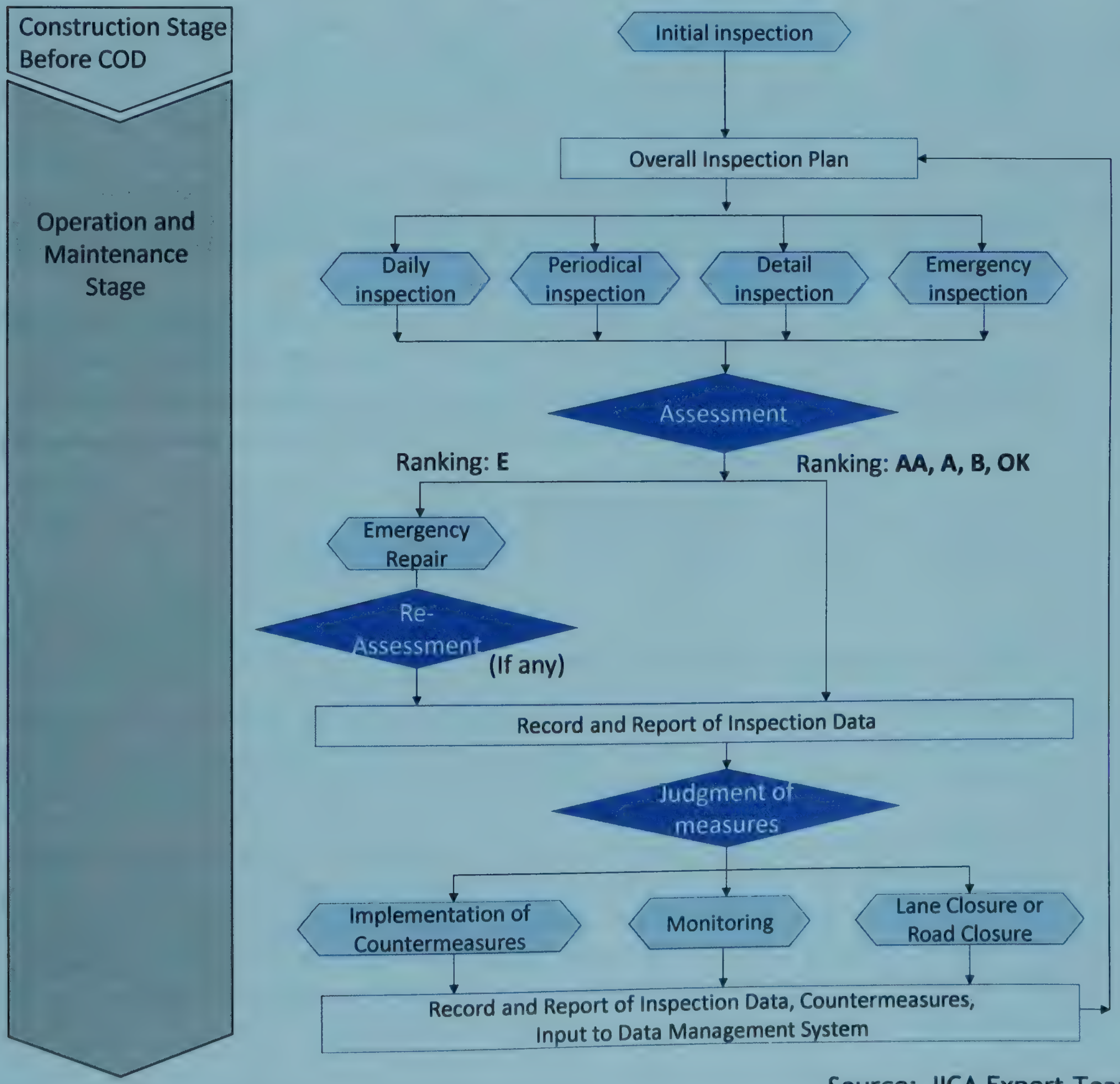
In general, spread foundation is more prone to scoring than those of pile foundation and caisson/well foundation in terms of safety of bridge structure. Severe damage by scours lead to the possibility of superstructure fall. In this case, prompt actions and countermeasures become necessary. Inspectors shall pay attention to the deformation of piers and abutment, including subsidence, movement, and leaning. For this purpose, it is advisable to inspect adjacent structures (e.g. drainage, block masonry), bearing, and joint gaps, ground level, and then comprehensively judge the status of deformation. These forms of deformation often lead to serious cases, for which maintenance work is very challenging. In this regard, it is critical to find the said deformation in as early a stage as possible~~,~~ and to conduct a subsequent follow-up investigation.

5.9 Assessment

5.9.1 Assessment Process

Inspection is not independent action, but rather a part of the integrated process of road maintenance. After the implementation of inspections, an assessment of inspection results shall be conducted as a next step. In the assessment, all the inspected results are accessed to categorize them into several groups according to the degree of degradation and importance of structure. For this purpose, uniform ranking criteria shall be adapted. After these processes, all the records are compiled in the maintenance data system.

The compiled data is used as a reference for the next inspections, and the process is reiterated. Therefore, the implementation of inspections has to be coordinated with the other related activities shown in Table 5-36, and all the processes have to be reviewed to see if the frequency of inspections, assessment method of the results, method of inspections, and selection of a repair method should be improved.


Construction Stage
Before COD
Operation and Maintenance Stage
Initial inspection
Overall Inspection Plan
Daily inspection
Periodical inspection
Detail inspection
Emergency inspection
Assessment
Ranking: E
Ranking: AA, A, B, OK
Emergency Repair
Re-Assessment
(If any)
Record and Report of Inspection Data
Judgment of measures
Implementation of Countermeasures
Monitoring
Lane Closure or Road Closure
Record and Report of Inspection Data, Countermeasures, Input to Data Management System

Source: JICA Expert Team

Figure 5-64: Process of Inspection, Assessment, and Repair

There are various symptoms of deterioration, which are very different from one structure to another on a route. The method of inspection differs as well. How a fault in a structure affects the serviceability of a road also differs from each other. Therefore, it is very difficult to assess deterioration with the same standard and accuracy. Taking account of the fact, Table 5-12 directs the basic principle of the judgment of how severe an inspected structure is.

All the damage observed shall be assessed and graded as AA (severe damage, needs very rapid repair), A1 – A2 (damage detected, needs repair in due time), B (damage, needs observation), C (inspection needed to judge the level of function), OK (no damage found, or slightly damaged). When an inspector finds that there is a danger of inflicting damage to third parties, the damage will be graded as E, requiring immediate repairs.

With regard to inspection of bridges, bridge structural members (deck slab of each span, superstructure, substructure) shall be assessed separately for planning repairs by group of structural members for each bridge spans.

Damages to pavement are judged using pre-decided criteria. When deterioration is progressing quickly and expected to reach the threshold level in a comparatively short period, the damage is rated as AA and shall be repaired immediately. The extent of cracking is the basic measurement used to judge pavement structural damage. When interior damage is suspected, deflection inspection shall be carried out.

Table 5-12: Defect Ranking of Inspection Results

Ranking			Typical Symptoms
Functional Deterioration	AA		Severe damage/ deformation. Immediate repair
	A		Damage/Deformation and functional deterioration. Repair but not immediately.
		A1	Not immediate repair, but has functional deterioration worsening rapidly
		A2	Not immediate repair, but has functional deterioration worsening gradually
	B		Damage/deformation, but no sign of functional deterioration. Requires continuous monitoring.
	OK		Slight or no damage/deformation
Emergency	E		Danger to third parties or safe traffic. Immediate repair

[16]

5.9.2 Inspection of Each Structure

The objective of inspection for road structures is to understand structure conditions appropriately in order to secure safe traffic, prevent damage to the third party before happens, maintain road structures with a sound condition for a long period.

For the implementation of inspection of each structure, the inspector should understand the contents of related chapters in this guideline and related manuals, presented in Chapter 5.1. This guideline elaborates important points for inspection as well as standard ranking criteria for evaluation of inspection results in each category of structure. For adaption of these criteria, local conditions, where the inspection is conducted, should be adequately taken into account.

Assessment ranking "E" is not stipulated in the tables in the following chapters; however, road operators shall assess inspection results in consideration of each location whether identified damage or deformation may become a threat to the traffic safety or the third parties.

Assessment of inspection result of pavement should be performed according to specific standard ranking criteria. This guideline aims to present typical criteria for solid judgment in accordance with structure type, element, and types of deformation.

5.9.2.1 Standard ranking criteria for earth structure

Earth structure plays a central role on the mountainous highways, and it is basically classified into two items; slope and auxiliary facility. The auxiliary facility should be inspected during slope inspection.

Table 5-13 through Table 5-21 show standard ranking criteria for the assessment of inspection results, which are performed for earth structure (i.e. cut, embankment, slope, etc.). Targeted earth structures include slope (cut and embankment), auxiliary facility (slope protection, road surface drainage, slope drainage, others), and others (natural slope).

As for the assessment of the auxiliary facility, the inspector should confirm inspected condition whether deformation or damage will lead to slope failure, in consideration of the purpose of the facility and surrounding slope environment.

In the place where a natural slope may affect road traffic due to its deformation or collapse, the inspector should confirm neighboring natural slopes during the course of inspection for earth structures.

Table 5-13: Inspection Target: Earth Structure (Cut, Embankment, Slope, etc.)

No.	Item	Assessment Ranking		
		AA	A (A1, A2)	B
1	Collapse of slope	The slope was collapsed and continue to be collapsed	The slope was collapsed slightly with less possibility of continuing	--
2	Crack, swelling, depression	Cracks, swelling or depression which will cause slope collapse	Cracks, swelling, or depression appears in a limited area, and may not lead to slope collapse	--
3	Descaling, gully erosion	Wide range descaling or gully erosion which will cause slope collapse	Descaling or gully erosion which may not lead to slope collapse	--
4	Sediment soil over drain ditch on a berm	The function of the drain ditch on the berm is disturbed due to fallen rocks or sand on the slope	The function of the drain ditch on the berm is not disturbed regardless of fallen rocks or sand on the slope	--
5	Seepage water	Seepage water with increasing water volume during heavy rain which may lead to slope collapse	Seepage water with increasing water volume during heavy rain is unlikely to cause slope collapse	Seepage water which may not cause slope collapse
6	Fallen trees	Fallen or inclined trees which will cause slope collapse	Fallen or inclined trees which may not cause slope collapse	Very thickly grown trees
7	Vegetation damage	Luxuriant hydrophilic plant on the weakened ground condition, which is caused by seepage water, may lead to slope collapse	- Covering rate of vegetat ion is less than 30 percent - Luxuriant hydrophilic plant on the weakened ground condition, which is caused by seepage water. Need boring investigation	- Covering rate of vegetation is between 30 percent and 70 percent - Extraordinary luxuriant weed
8	Silting	Silting causing slope drainage function	Silting which does not affect drainage function	Small Silting
9	Flaking stone, boulders	Very unstable flaking stones or boulders on the slope which may fall on the carriageway	Unstable flaking stones or boulders on the slope	--

[16]

Table 5-14: Inspection Target: Cut (Upper slope)

No.	Item	Assessment Ranking		
		AA	A (A1, A2)	B
1	Change of circumstances behind the cut slope	- Inflow of water to cut slope from backland area due to land development, which may lead to slope collapse - Scarf or cracks in backland, which may lead to cut slope collapse	Scarf or cracks in backland, which need boring investigation	--

[16]

Table 5-15: Inspection Target: Concrete block/ Cast in place crib slope

No.	Item	Assessment Ranking		
		AA	A (A1, A2)	B
1	Cracks, stripping	Substantial crack or stripping which will fall	Wider spread crack or stripping	Partial crack or stripping which is unlikely to grow
2	Looseness, bulging, subsidence	Substantial looseness, bulging, subsidence resulting in falls or collapse	Looseness, bulging, subsidence with less possibility of growing	--
3	Drainage, seepage	Large seepage from joint or stuffed drainage pipe resulting in falls or collapse	--	Seepage from joint or stuffed drainage pipe which may not result in falls or collapse

[16]

Table 5-16: Inspection Target: Mortar/Concrete Spraying Slope, Concrete Lining Slope

No	Item	Assessment Ranking		
		AA	A(A1, A2)	B
1	Cracks, stripping	Substantial crack or stripping which will fall	Wider spread crack or stripping which will grow	Partial crack or stripping which is unlikely to grow
2	Looseness, bulging, subsidence	Resulting in falls or collapse	Less possibility of growing	--
3	Cavity	--	--	Possibility of cavity
4	Drainage, seepage	Large seepage from joint or stuffed drainage pipe resulting in falls or collapse	--	Seepage from joint or stuffed drainage pipe which may not result in falls or collapse

[16]

Table 5-17: Inspection Target: Falling Stone Prevention Net / Fence

No.	Item	Assessment Ranking		
		AA	A (A1, A2)	B
1	Damage to net /fence	Breakage or fall off of net/rope, the inclination of the column, resulting in loss of function	Wide-spread damage to net, rope, or column	Damage to net, rope, or column
2	Damage of accessories	Stopper, anchor bolts for lift stopping or set bolts: substantial breakage	--	Stopper, anchor bolts for lift stopping or set bolts: cracks or looseness
3	Corrosion	--	Wide-spread corrosion	Partial corrosion
4	Damage to foundation	Lifting of anchor, scour around foundation resulting in damage to net/fence proper	Lifting of anchor, scour around the foundation	The partial lifting of anchor, scour around the foundation

[16]

Table 5-18: Inspection Target: Concrete Block / Stone Masonry

No.	Item	Assessment Ranking		
		AA	A (A1, A2)	B
1	Cracks, looseness, bulging	Substantial crack, looseness, or bulging resulting in falls or collapse	Wider spread crack or stripping which will grow	Partial crack or stripping which is unlikely to grow
2	Settlement, displacement, inclination	The substantial settlement, displacement, or inclination resulting in falls or collapse	Settlement, displacement, or inclination which will grow	The partial settlement, displacement, or inclination which is unlikely to grow
3	Joint gap	Substantial joint gap resulting in falls or collapse	The substantial joint gap which will grow	The partial joint gap which is unlikely to grow
4	Scour	Substantial scour around the foundation or behind block resulting in falls or collapse	Scour around the foundation or behind block resulting in falls or collapse which will grow	Partial scour around the foundation or behind block which is unlikely to grow
5	Drainage, seepage	Large seepage from joint or stuffed drainage pipe resulting in falls or collapse	--	Seepage from joint or stuffed drainage pipe which may not result in falls or collapse

[16]

Table 5-19: Inspection Target: Concrete Retaining Walls (Reinforced Concrete)

No.	Item	Assessment Ranking		
		AA	A (A1, A2)	B
1	Cracks, corner failure	Substantial cracks into reinforced bars resulting in falls	Cracks into reinforced bars	Partial Cracks
2	Stripping		Large stripping	Partial stripping
3	Exposure and corrosion of reinforcement		Steel is remarkably exposed and corroded	Steel is partially exposed
4	Joint gap	Substantial joint gap resulting in falls or collapse	The substantial joint gap which will grow	The partial joint gap which is unlikely to grow
5	Settlement, movement, Tilting	The substantial settlement, movement, Tilting resulted in falls	Settlement, movement, Tilting which needs investigation	Small Settlement, movement, Tilting
6	Scour	Substantial scour around the foundation	Scour around foundation	Partial scour around the foundation or behind block which is unlikely to grow
7	Leakage	Substantial leakage	--	Leakage

[16]

Table 5-20: Inspection Target: Concrete Retaining Walls (Non Reinforced Concrete)

No.	Item	Assessment Ranking		
		AA	A (A1, A2)	B
1	Cracks, corner failure	Substantial cracks resulting in falls	Large cracks or corner failure will grow	Partial cracks or corner failure which is unlikely to grow
2	Joint gap	Substantial joint gap resulting in falls or collapse	The substantial joint gap which will grow	The partial joint gap which is unlikely to grow
3	Settlement, movement, Tilting	The substantial settlement, movement, Tilting resulted in falls	Settlement, movement, Tilting which needs investigation	Small Settlement, movement, Tilting
4	Scour	Substantial scour around the foundation	Scour around foundation	Partial scour around the foundation or behind block which is unlikely to grow
5	Leakage	Substantial leakage	--	Leakage

[16]

Table 5-21: Inspection Target: Slope Drainage

No.	Item	Assessment Ranking		
		AA	A (A1, A2)	B
1	Damage to the facility	Drain ditch, vertical ditch damage-causing overflow or slope failure	Drain ditch, vertical ditch damage resulting in remarkable functional lowering The lid is off or damaged causing functional lowering	--
2	Bad connection	Water leakage causing slope failure	--	Water leakage which is unlikely to cause slope failure
3	Silting	Silting results in loss of drainage function which will cause slope failure	Silting results in stagnant water on the slope surface	Silting which will not affect drainage function
4	Weeds	Grown weeds result in loss of drainage function which will cause slope failure	--	Weed which will not affect drainage function

[16]

5.9.2.2 Standard ranking criteria for bridges

This subsection elaborates standard ranking criteria for the evaluation of inspection results on bridges located on mountainous highways. The intended elements of the bridge which the standard ranking criteria is adapted are as follows:

- Steel bridge
- Concrete bridge, prestressed concrete bridge
- Hybrid material bridge
- Bridge slab
- Substructure
- Bearing
- Joint

- Bridge accessories (railing, drainage system, anti-collapse prevention system, inspection corridor)
- Pavement on bridge
- Pedestrian overpass
- Other accessories for bridge

The criteria can be applied to the common and typical bridge inspection; however, specific consideration and/or approach may be necessary, where appropriate, by a good understanding of this chapter and taking account of structure type, location, used material for a targeted bridge, surrounding environment, condition used. If a special inspection manual is created and adapted for a special bridge, including a cable suspension bridge, cable-stayed bridge, arch bridge, and other new types of bridge, such manual should be adapted for the decision of criteria ranking.

Moreover, appropriate inspection judgement shall be consolidated by adequate information of design and construction. Related guidelines and manuals should be referred to for this purpose.

In some cases, judgement of inspection results may be difficult by only close visual check by inspectors. In such a case, the road administrator should consult with relevant specialists and/or professionals in academics, and conduct a detailed investigation, where necessary, in order to determine a cause of deterioration and estimate the deterioration mechanism.

Table 5-22: Inspection Target: Steel Structures (Girder, Plate Deck, Pier, Cross Beam)

No.	Item	Assessment Ranking		
		AA	A (A1, A2)	B
1	Cracks	Substantial cracks	Cracks	
2	Deformation	Heavily deformed which affects load strength	Deformed	Partial deformation of the member
3	Loss or looseness of high tensile bolts	Several bolts missing at each joint part (More than 20% missing in the connection)	A few bolts missing at each joint part (20% missing in the connection)	Bolt missing
4	Loss or looseness of rivets	Several rivets missing at each joint part (More than 20% missing in the connection)	A few rivets missing at each joint part (20% missing in the connection)	Rivet missing
5	Corrosion	Entirely and remarkably corroded which affects load strength	Widely corroded which affects load strength	Corroded
6	Unusual noise and vibration	–	Unusual noise vibration caused by shaking, creaking, or impacts by vehicle	Unusual noise and vibration
7	Surface painting	–	Wide spread damage by crack, Swelling, pitting, or rust	Partial damage by crack, Swelling, pitting, or rust
8	Water leakage stagnant water	--	Main structural member: widely corroded due to water leakage Inside of box girder: widely corroded due to stagnant water	Main structural member: Partial corroded due to water leakage Inside of box girder : partially corroded due to stagnant water

[16]

Table 5-23: Inspection Target: Concrete Superstructures

No.	Item	Assessment Ranking		
		AA	A (A1, A2)	B
1	Cracks	Substantial cracks	Large Cracks	--
2	Stripping	Substantial stripping	Large stripping	Partial stripping
3	Exposure and corrosion of reinforcement	Steel reinforcement is remarkably exposed and corroded	Steel reinforcement is largely exposed and corroded	Steel reinforcement is partially exposed
4	PC steel breakage	PC steel is cut off	Attachment of PC steel is cracked or rust	--
5	Void and honeycomb	--	Remarkable air voids or honeycombs	Air voids or honeycombs partially
6	Deflection, unusual vibration	--	Unusual water stagnation on bridge deck recurs Excessive deflection observed Abnormal vibrations observed	--
7	Unusual noise and vibration	--	Unusual noise vibration caused by shaking, creaking, or impacts by vehicle	Unusual noise and vibration
8	Water leakage	--	Continuous water leakage	Water leakage during rains
9	Surface colour change	--	Colour change with cracks	Partial colour change
10	Rust fluid	--	Substantial Rust fluid	Partial rust fluid

[16]

Table 5-24: Inspection Target: Abutments and Piers

No.	Item	Assessment Ranking		
		AA	A (A1, A2)	B
1	Cracks	Substantial cracks near the bearing	Cracks into reinforced bars	Partial cracks
2	Stripping	Substantial stripping	Large stripping	Partial stripping
3	Exposure and corrosion of reinforcement	--	Steel reinforcement is remarkably exposed and corroded	Steel reinforcement is partially exposed
4	Void and honeycomb	--	Remarkable air voids or honeycombs	Air voids or honeycombs partially
5	Rust fluid	--	Substantial Rust fluid	Partial rust fluid
6	Settlement, movement, tilting	--	Damaged due to Settlement, movement, tilting	Partially damaged due to Settlement, movement, tilting
7	Scour	Substantial scour around the foundation	Scour around foundation	Partial scour around the foundation or behind block which is unlikely to grow

[16]

Table 5-25: Inspection Target: Steel Bearings

No.	Item	Assessment Ranking		
		AA	A (A1, A2)	B
1	Damage of structure	Heavy damage of the main structure	Upper, lower bearing: restricted function of rotation or movement due to breakage, settlement, or tilting	Upper, lower bearing: cracks or tilting
2	Damage of accessories	--	Stopper, anchor bolts for lift stopping or set bolts: breakage	Stopper, anchor bolts for lift stopping or set bolts: cracks or looseness
3	Corrosion	Heavily corroded affecting load strength	Remarkably corroded reducing to load strength	Partially corroded affecting function of rotation or movement
4	Damage of bearing pedestal concrete, nearing pedestal mortar, protection mortar	Remarkably breakage	Bearing pedestal concrete: widely cracked Bearing pedestal mortar: air voids or cracks	Protection mortar : cracks
5	Inadequate clearance	Loss of load strength	Rotation or movement of girders: completely restricted	Rotation or movement of girders: restricted
6	Unusual noise	--	Large and unusual noise	Unusual noise
7	Silting	--	Buried in accumulated soil and dust	Accumulated soil and dust around bearings

[16]

Table 5-26: Inspection Target: Rubber Bearings

No.	Item	Assessment Ranking		
		AA	A (A1, A2)	B
1	Deterioration of Rubber	Heavily deteriorated affecting to load strength	Crack, blister	Partial crack, blister
2	Damage of bearing pedestal concrete, nearing pedestal mortar, protection mortar	Remarkably corroded affecting to load strength	Bearing pedestal concrete: widely cracked Bearing pedestal mortar: air voids or cracks	Protection mortar: cracks or spalling
3	Silting	--	Buried in accumulated soil and dust	Accumulated soil and dust around bearings

[16]

Table 5-27: Inspection Target: Joints

No.	Item	Assessment Ranking		
		AA	A (A1, A2)	B
1	Damage of joint	-Damage to welding part - Lifting of face plate or rubber -Missing anchor bolt	Breakage of face rubber	--
2	Damage around joint	--	Hollow or lump: over 1 m in length over 5 cm in width	--
3	Faulting	Over 20 mm	10 mm to 20 mm	--
4	Abnormality in spacing	--	Closed spacing and possibility of bad influence to the bridge structure Abnormal opening of spacing and abnormal sound	Abnormally narrow spacing The wide opening of spacing
5	Water Seepage	--	Water seepage from the joint which affects other bridge members	--
6	Abnormal sound	--	Abnormal sound on vehicle passage	--

[16]

Table 5-28: Inspection Target: Joints

No.	Item	Assessment Ranking		
		AA	A (A1, A2)	B
1	Damage of joint	-Damage to welding part - Lifting of face plate or rubber -Missing anchor bolt	Breakage of face rubber	--
2	Damage around joint	--	Hollow or lump: over 1 m in length over 5 cm in width	--
3	Faulting	Over 20 mm	10 mm to 20 mm	--
4	Abnormality in spacing	--	Closed spacing and possibility of bad influence to the bridge structure Abnormal opening of spacing and abnormal sound	Abnormally narrow spacing The wide opening of spacing
5	Water Seepage	--	Water seepage from the joint which affects other bridge members	--
6	Abnormal sound	--	Abnormal sound on vehicle passage	--

[16]

Table 5-29: Inspection Target: Railing and Curb (Steel Railing)

No.	Item	Assessment Ranking		
		AA	A (A1, A2)	B
1	Damage	--	Deformation or cracks in the wide area	Deformation or cracks in limited part or falling of bolts
2	Corrosion	--	Corrosion in the wide area	Corrosion in a limited part

[16]

Table 5-30: Inspection Target: Railing and Curb (Concrete Railing)

No.	Item	Assessment Ranking		
		AA	A (A1, A2)	B
1	Crack	Substantial cracks resulting in falls	Cracks into reinforced bars	Partial Cracks
2	Stripping	--	Large stripping	Partial stripping
3	Exposure and corrosion of reinforcement	--	Steel reinforcement is remarkably exposed and corroded	Steel reinforcement is partially exposed
4	Free lime	--	Free lime causing corrosion	Partial free lime
5	Water leakage	--	Continuous water leakage	Water leakage during rains
6	Surface color change	--	Colour change with cracks	Partial colour change
7	Rust fluid	--	Substantial Rust fluid	Partial rust fluid

[16]

Table 5-31: Inspection Target: Bridge Drainage (Catch Basin)

No.	Item	Assessment Ranking		
		AA	A (A1, A2)	B
1	Damage to the facility	Damage causing overflow during rains or causing damage of structures	Damage affecting drainage function	--
2	Damage to the lid	The lid is off or remarkable damage	--	Damage causing functional lowering
3	Silting	Silting resulting in overflow	Silting results in lowering of drainage function which causes stagnant water	Temporary stagnant water

[16]

Table 5-32: Inspection Target: Bridge Drainage (Drainage Pipe and Joint)

No.	Item	Assessment Ranking		
		AA	A (A1, A2)	B
1	Damage to the facility	Damage causing overflow during rains or causing damage of structures	Damage affecting drainage function	--
2	Bad connection	Water leakage affects bearing or other bridge members	--	--
3	Silting	Silting resulting in overflow	Silting results in lowering of drainage function which causes stagnant water	Temporary stagnant water

[16]

5.9.2.3 Standard ranking criteria for tunnel

This subsection elaborates standard ranking criteria for the evaluation of inspection results on tunnels. The intended elements of a tunnel which the standard ranking criteria is adapted are as follows:

- Tunnel lining
- Portal
- Interior wall
- Ceiling slab
- Drainage

Detailed inspection for tunnel lining shall be basically conducted by close visual check and hammering. Spots of hammering shall be generally the location where an inspector finds it necessary to hammer by his or her close eye visual check. In addition, such hammering should be performed also in a priority section or points, which are determined by advanced inspection method, if any, such as tunnel lining measurement vehicle, listed in Table 5-3.

Moreover, appropriate inspection judgement shall be consolidated by adequate information on the design and construction of a targeted tunnel. Related guidelines and manuals should be referred to for this purpose. In some cases, judgement of inspection results may be difficult by only close visual check by inspectors. In such a case, the road administrator should consult with relevant specialists and/or professionals in academics, and conduct a detailed investigation, where necessary, in order to determine a cause of deterioration and estimate the deterioration mechanism.

Table 5-33: Inspection Target: Tunnel (Lining)

No.	Item	Assessment Ranking		
		AA	A (A1, A2)	B
1	Cracks, corner failure	Substantial cracks resulting in falls	Cracks: more than 0.3 mm wide and progressing	Cracks: more than 0.3 mm wide and not progressing
2	Stripping	Substantial concrete stripping	Thick concrete stripping	Thin concrete stripping
3	Leakage, free lime	Substantial leakage, free lime	--	leakage, free lime
4	Abnormality in a joint	--	Discrepancy, gap, or difference with expanding	Discrepancy, gap, or difference without expanding

[16]

Table 5-34: Inspection Target: Tunnel (Portal)

No.	Item	Assessment Ranking		
		AA	A (A1, A2)	B
1	Cracks, corner failure	Substantial cracks resulting in falls	Cracks: more than 0.3 mm wide and not progressing	Cracks: more than 0.3 mm wide and not progressing
2	Stripping	--	Substantial stripping	Partial stripping
3	Exposure and corrosion of reinforcement	--	Steel reinforcement is remarkably exposed and corroded	Steel reinforcement is partially exposed
4	Settlement, movement, tilting	Progressing settlement, movement, tilting Bad influence to upper slope	A small settlement, movement titling	--
5	Abnormality in joint	--	The discrepancy, gap, or difference with expanding	The discrepancy, gap, or difference without expanding
6	Scour	--	Surroundings, of footing, body, and wing; remarkably scoured	Surroundings, of footing, body, and wing; scoured
7	Drainage, spring water	--	Abnormal spring water from a joint resulting in stagnant water	Leakage from a joint

[16]

Table 5-35: Inspection Target: Tunnel (Interior Wall)

No.	Item	Assessment Ranking		
		AA	A (A1, A2)	B
1	Damage to the wall	--	Breakage or separation in wide area Remarkable dirt wholly	Breakage or separation in a part
2	Damage to the accessories	--	Fittings, bolts: breakage, lost, remarkable rust Possibility of fall of the wall	Fittings, bolts: breakage, lost, remarkable rust

[16]

Table 5-36: Inspection Target: Tunnel (Ceiling Slab)

No.	Item	Assessment Ranking		
		AA	A (A1, A2)	B
1	Damage to the slab	--	Remarkable Breakage or separation	Breakage or cracks
2	Damage to the accessories	--	Suspenders, fittings, bolts: breakage, lost, remarkable rust	Suspenders, fittings,: breakage, rust

[16]

Table 5-37: Inspection Target: Tunnel (Drainage)

No.	Item	Assessment Ranking		
		AA	A (A1, A2)	B
1	Damage to the drainage facility	Remarkable damage due to the lateral or vertical stress affecting drainage function	Damage due to the lateral or vertical stress affecting drainage function	--
2	Silting	Silting resulting in overflow	Silting resulting in lowering of drainage the function which causes stagnant water	Temporary stagnant water

[16]

5.9.2.4 Standard ranking criteria for culvert

This subsection elaborates standard ranking criteria for the evaluation of inspection results on culvert structure. The intended type of culvert is as follows:

- Reinforced Concrete Box
- Reinforced Concrete Pipe
- Corrugated Steel Pipe and Other Type Culvert

This section elaborates standard ranking criteria; therefore, appropriate decision-making on assessment ranking should be performed based on each targeted culvert, where necessary. In case a drainage gutter is installed in a culvert, assessment of such gutter should be performed by the criteria of gutter in a tunnel.

Moreover, appropriate inspection judgement shall be consolidated by adequate information on the design and construction of a targeted culvert. Related guidelines and manuals should be referred to for this purpose.

In some cases, judgement of inspection results may be difficult by only close visual check by inspectors. In such a case, the road administrator should consult with relevant specialists and/or professionals in academics, and conduct a detailed investigation, where necessary, in order to determine a cause of deterioration and estimate the deterioration mechanism.

Table 5-38: Inspection Target: Reinforced Concrete Box

No.	Item	Assessment Ranking		
		AA	A (A1, A2)	B
1	Cracks	Substantial cracks resulting in falls	Cracks into reinforced bars	Partial Cracks
2	Stripping	--	Large stripping	Partial stripping
3	Exposure and corrosion of reinforcement	--	Steel reinforcement is remarkably exposed and corroded	Steel reinforcement is partially exposed
4	Air void, honeycomb	--	Remarkable air voids or honeycombs	Air voids or honeycombs partially
5	Leakage, free lime	--	Substantial leakage, free lime causing corrosion	leakage, free lime
6	Un-even settlement	--	Stagnant water in a water channel or a culvert Bump at the connection to an approach road Remarkable scour around the wing	Functional lowering of water channel Scour around wing
7	Abnormality in joint	--	High dropping the possibility of joint sealing material or falling cut-off plate because of discrepancy, gap, or difference	Discrepancy, gap, or difference

[16]

Table 5-39: Inspection Target: Reinforced Concrete Pipe

No.	Item	Assessment Ranking		
		AA	A (A1, A2)	B
1	Cracks	Remarkable cracks into reinforced bars causing the breakdown	Cracks into reinforced bars	Partial Cracks
2	Stripping	Remarkable stripping into reinforced bars causing the breakdown	Large stripping	Partial stripping
3	Exposure and corrosion of reinforcement	--	Steel reinforcement is remarkably exposed and corroded	Steel reinforcement is partially exposed
4	Settlement	--	Remarkable lowering of drainage function Stagnant water	Lowering of drainage function
5	Damage of joint	--	Discrepancy, gap, breakage Leakage	Discrepancy, gap
6	Silting	--	Remarkable lowering of drainage function Stagnant water	Lowering of drainage function
7	Scour	--	Stagnant water in a water channel or a culvert Remarkable scour around the pipe	Functional lowering of water channel Scour around pipe

[16]

Table 5-40: Inspection Target: Corrugated Steel Pipe and Other Type Culvert

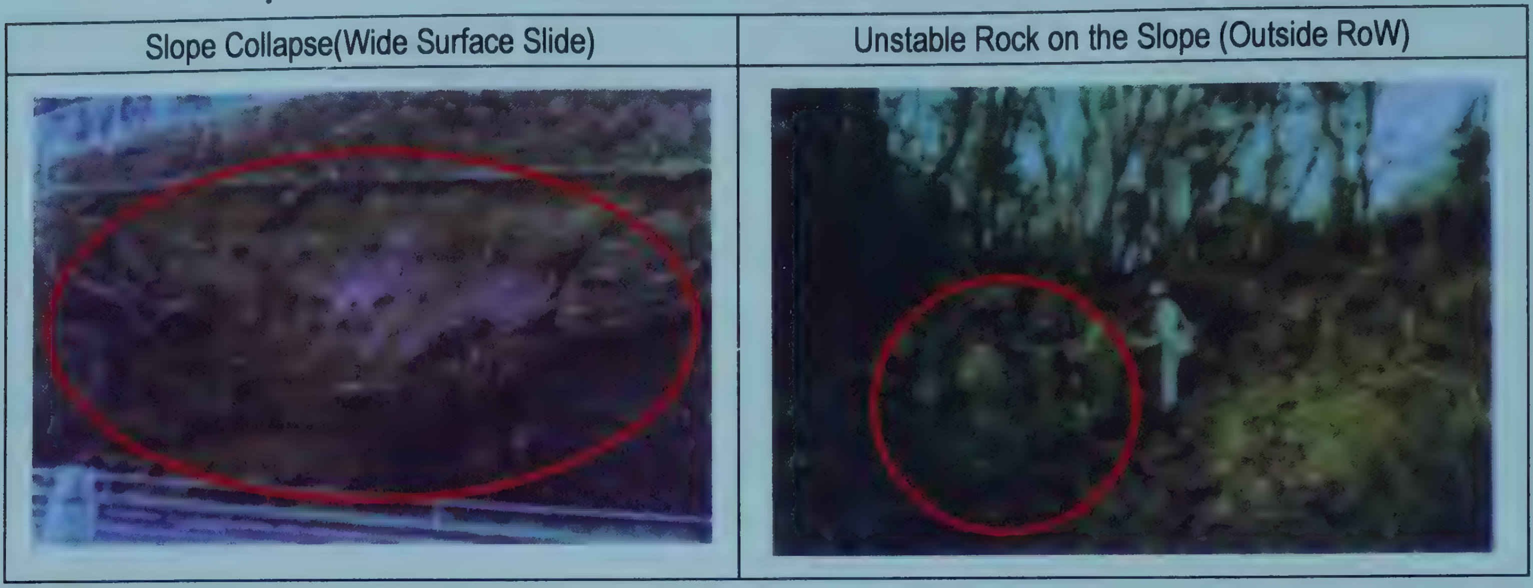
No.	Item	Assessment Ranking		
		AA	A (A1, A2)	B
1	Damage of culvert	--	Large deformation or remarkable cracks	Deformation or cracks
2	Corrosion	--	Remarkable corrosion in the wide area	Partial corrosion
3	Settlement	--	Remarkable lowering of drainage function Stagnant water	Lowering of drainage function
4	Damage of joint	--	Discrepancy, gap, breakage Leakage	Discrepancy, gap
5	Silting	--	Remarkable lowering of drainage function Stagnant water	Lowering of drainage function

[16]

5.9.3 Typical Damage and Distress

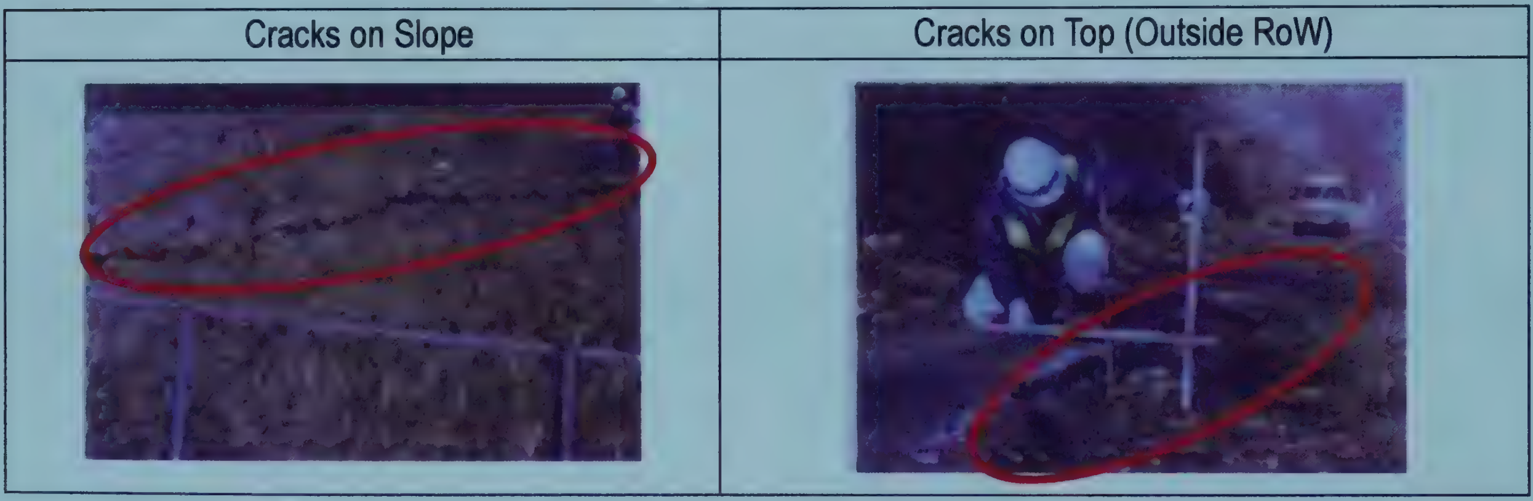
This section aims to present visual examples of typical damages and distress according to classifications.

5.9.3.1 Typical damage and distress of earth structure


Slope Collapse(Wide Surface Slide)
Unstable Rock on the Slope (Outside RoW)

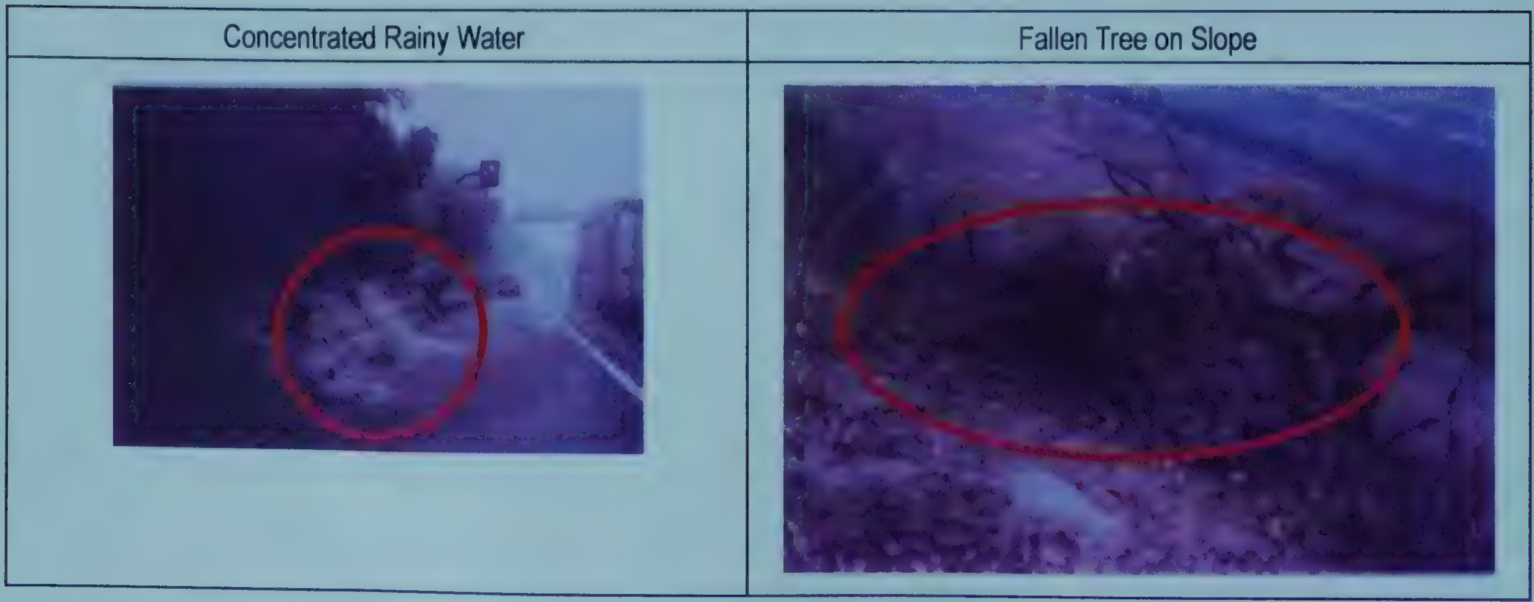
[16]

Figure 5-65: Slope Collapse (Ranking AA)


Cracks on Slope
Cracks on Top (Outside RoW)

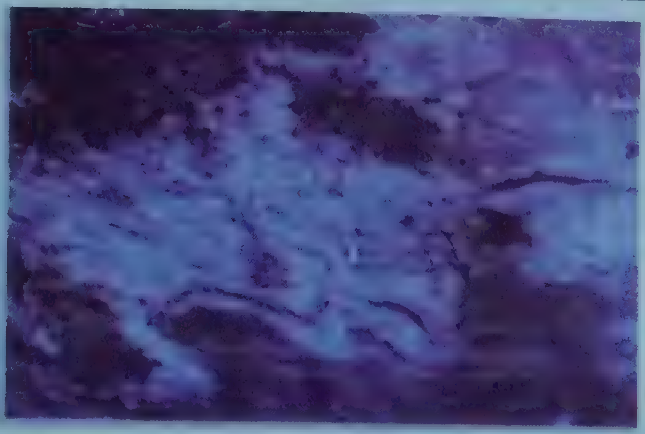
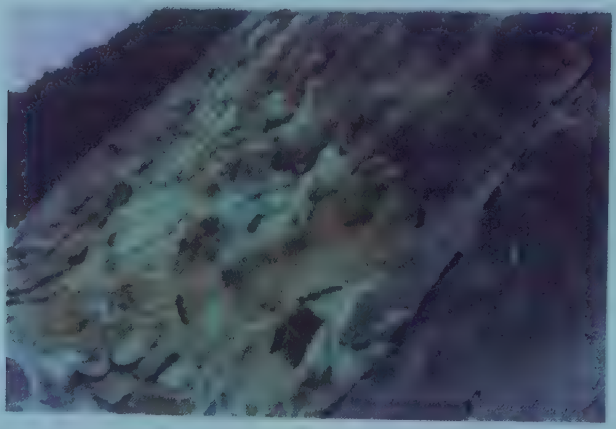
[16]

Figure 5-66: Cracks on Slope (Ranking AA)


Concentrated Rainy Water
Fallen Tree on Slope

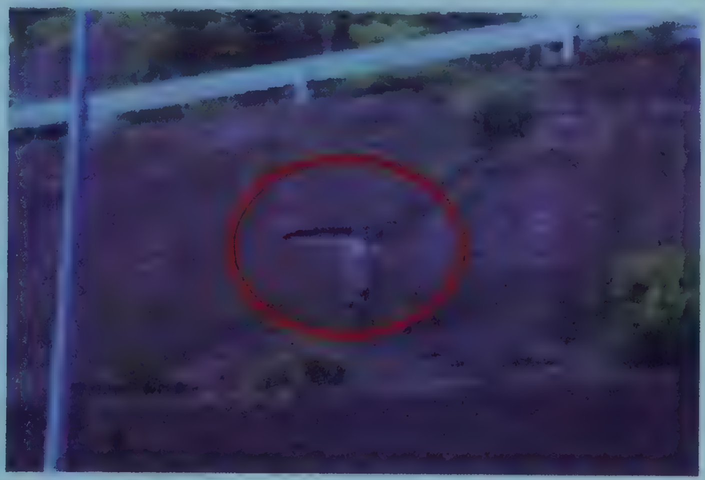
[16]

Figure 5-67: Seepage Water and Fallen Tree on slope (Ranking AA)

Weathered Concrete Spraying (Wire net exposed)	Weathered Concrete Spraying (Wide Range)
	

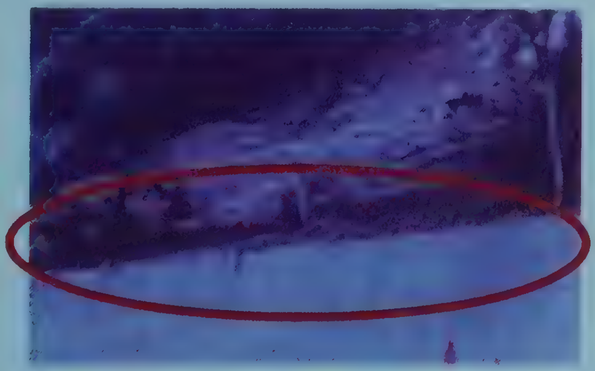
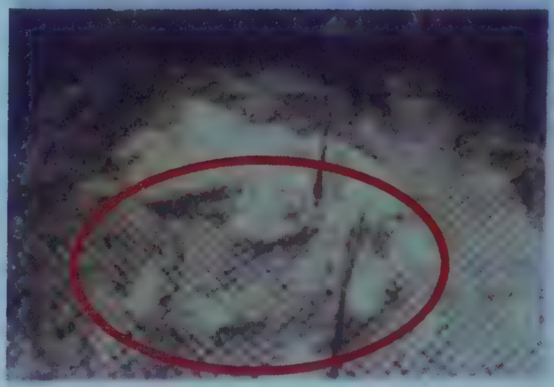
[16]

Figure 5-68: Weathered Concrete Spraying Slope (Ranking A)

Partial Cracks on Concrete Spraying Slope


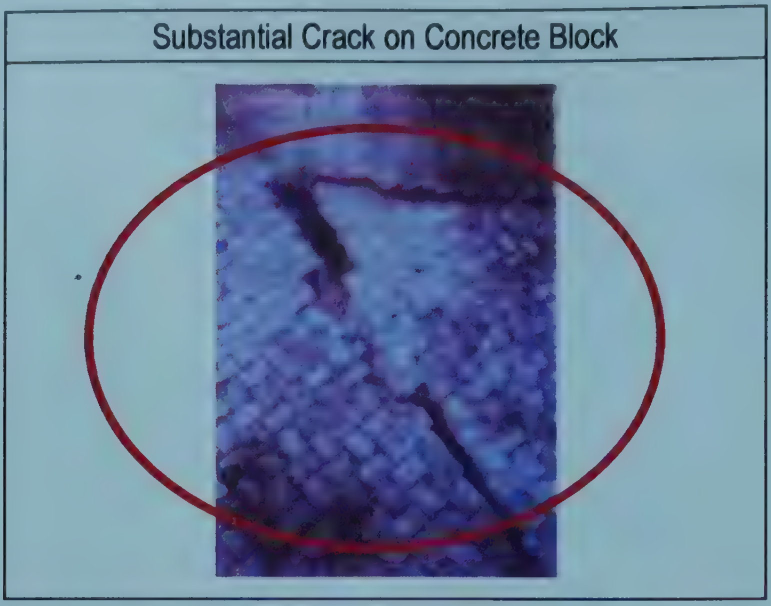
[16]

Figure 5-69: Damage of Concrete Spraying Slope (Ranking B)

Deformed Wire Net and Support	Corroded Wire Net
	

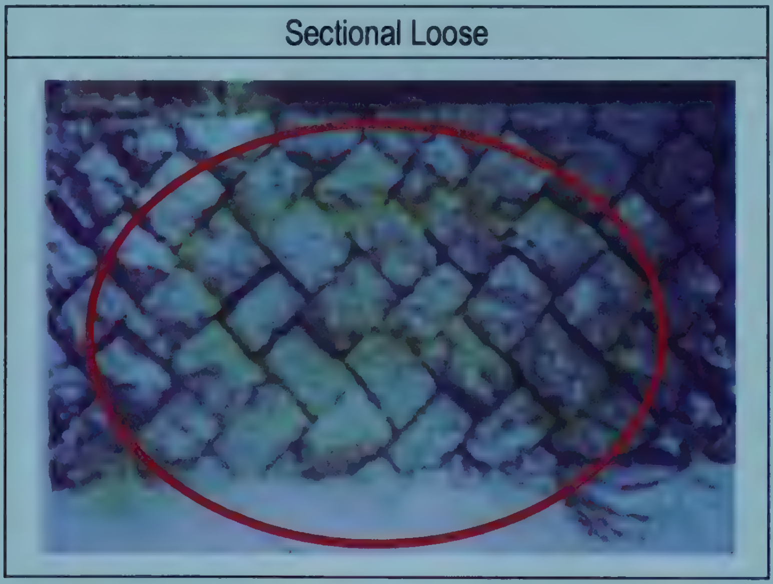
[16]

Figure 5-70: Damage of Slope Protection Column (Ranking AA)


Substantial Crack on Concrete Block

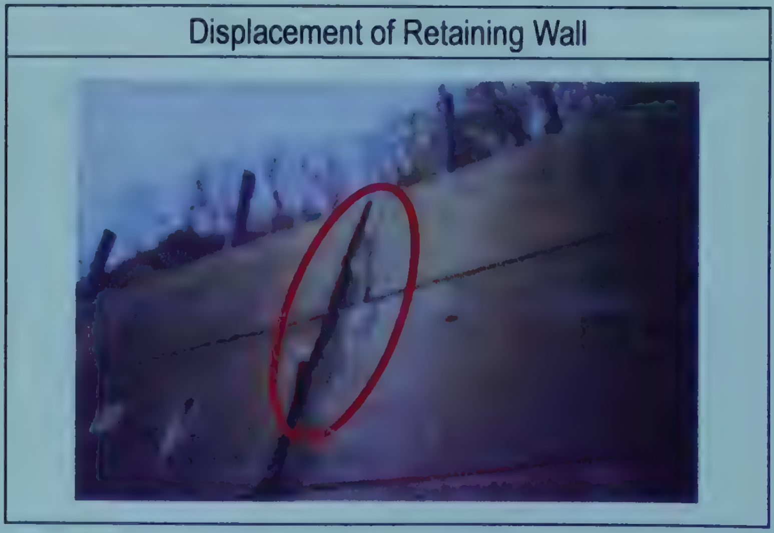
[16]

Figure 5-71: Damage of Concrete Block (Ranking AA)


Sectional Loose

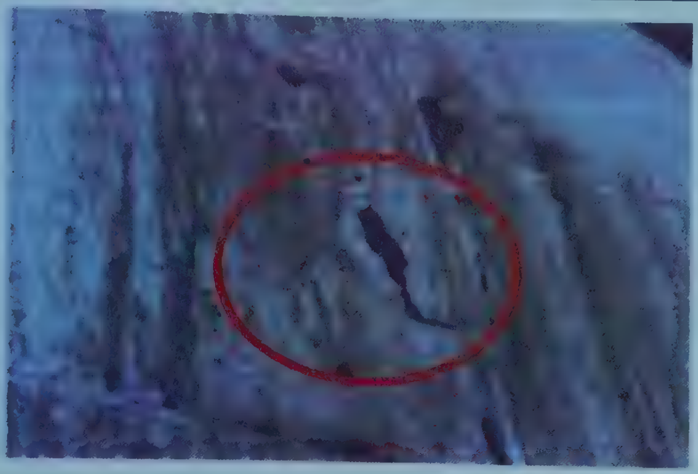
[16]

Figure 5-72: Sectional Loose on Concrete Block (Ranking B)


Displacement of Retaining Wall

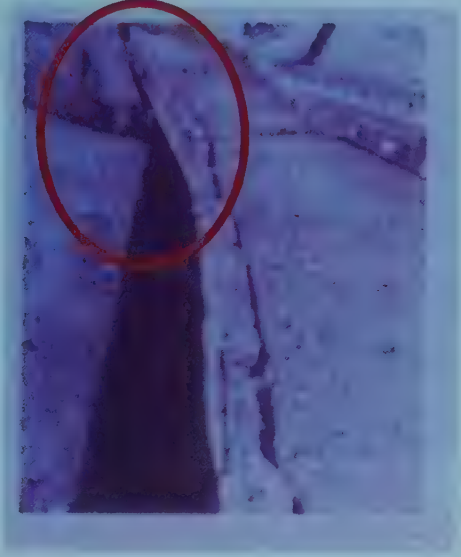
[16]

Figure 5-73: Displacement of Retaining Wall (Ranking A)

Partial Abrasion on Surface of Retaining Wall


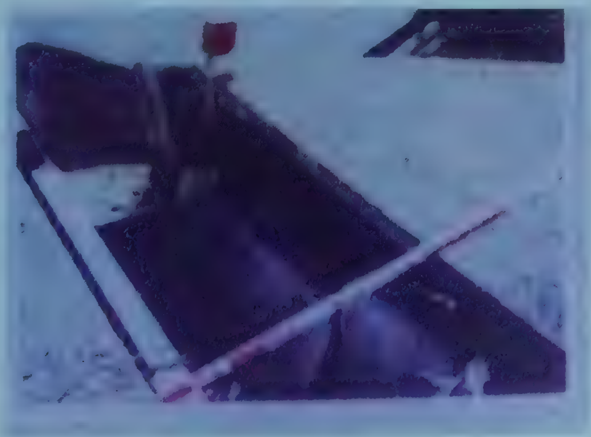
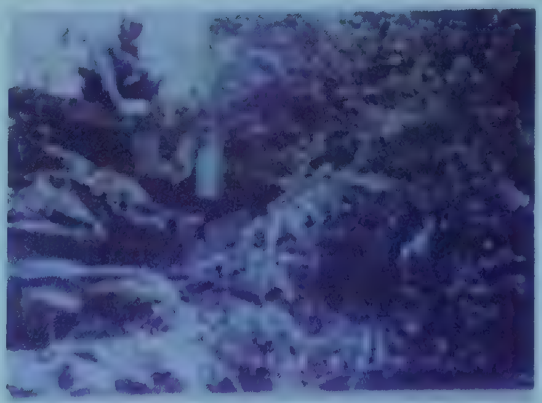
[16]

Figure 5-74: Partial Stripping (Ranking B)

Drain Damage caused by Slope Failure


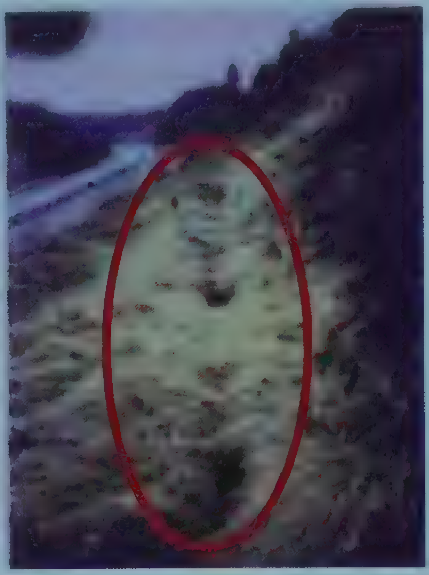
[16]

Figure 5-75: Drainage Failure (Ranking AA)

Drainage Failure due to Water Leakage	Vertical Drain Damage due to Water Leakage
	

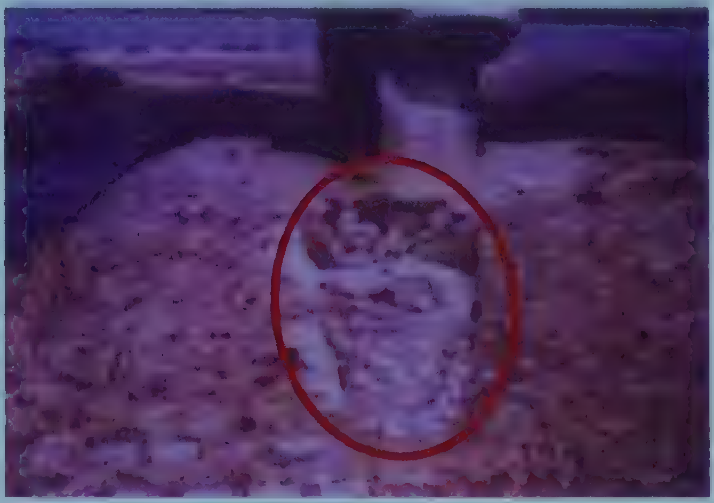
[16]

Figure 5-76: Poor Drainage Connection (Ranking AA)

Drainage covered with Weed


[16]

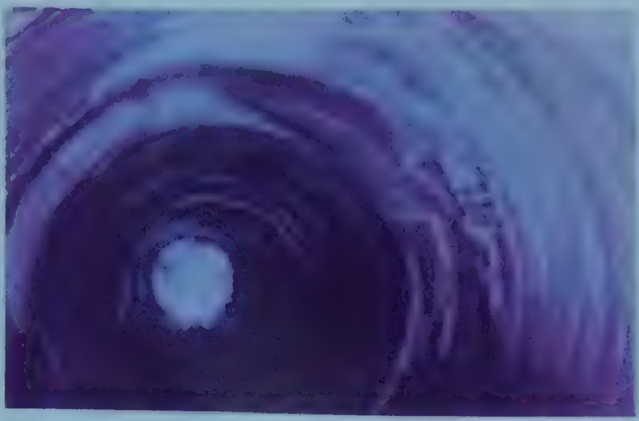
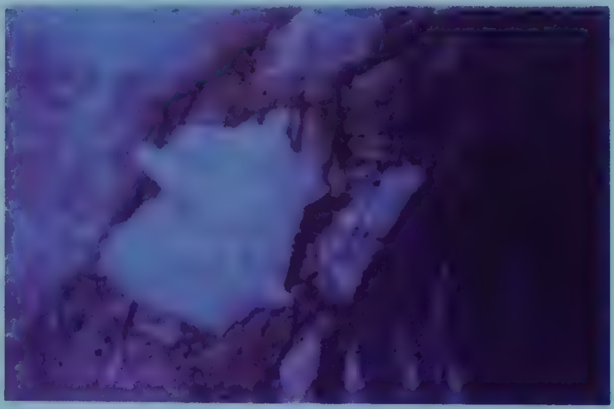
Figure 5-77: Loss of Drainage Function (Ranking AA)

Partial scour around the foundation


[16]

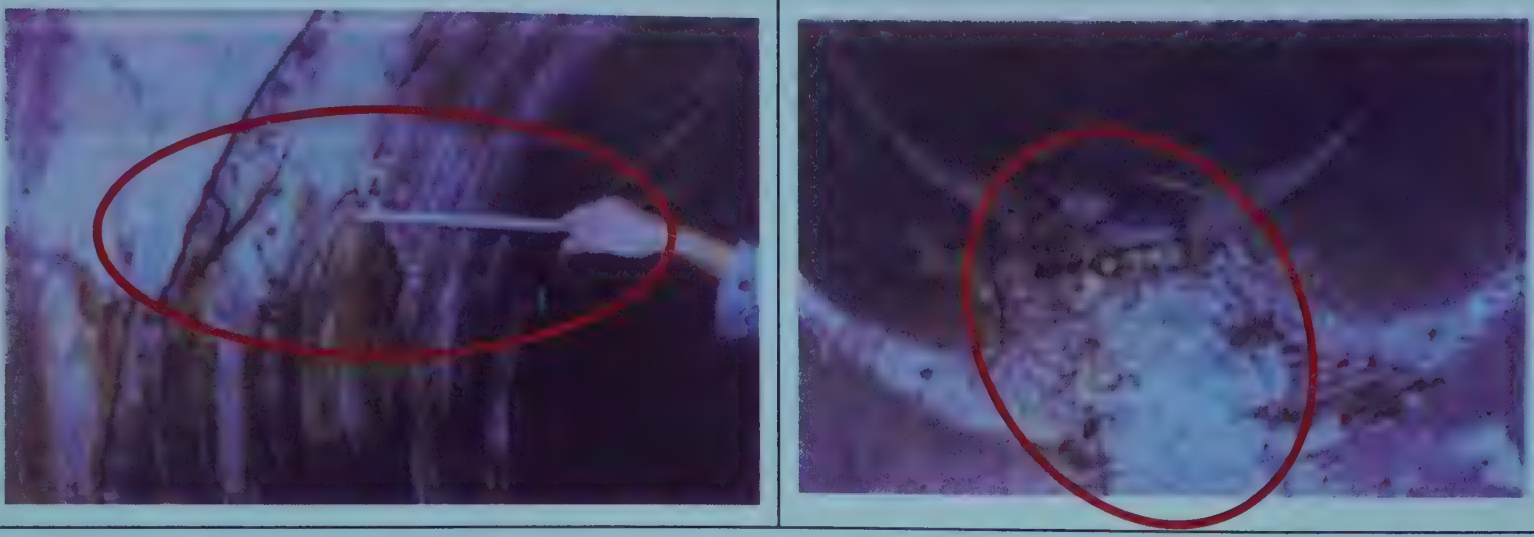
Figure 5-78: Scour around Foundation (Ranking B)

5.9.3.2 2.2.3.5 Typical damage and distress of Culvert Pipe

Remarkable cracks into reinforced bars and deformation causing breakdown	Remarkable stripping into reinforced bars causing the breakdown
	

[16]

Figure 5-79: Crack and Stripping (Ranking AA)

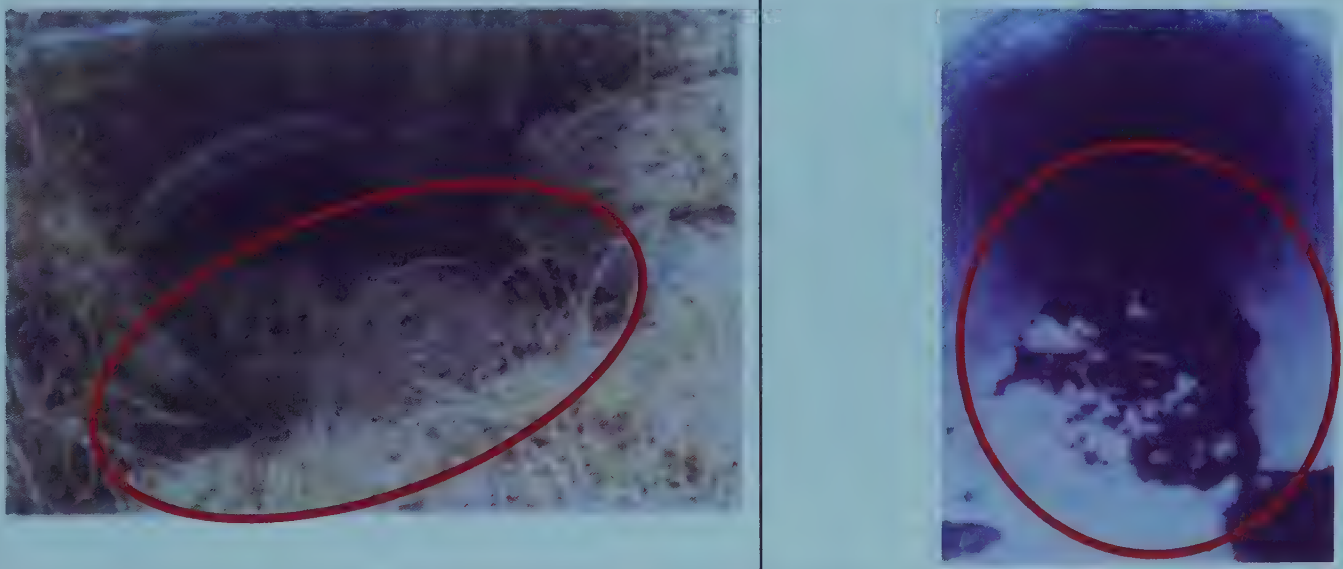


Large stripping

Remarkable scour on the bottom of the pipe

[16]

Figure 5-80: Stripping and Scour (Ranking A)

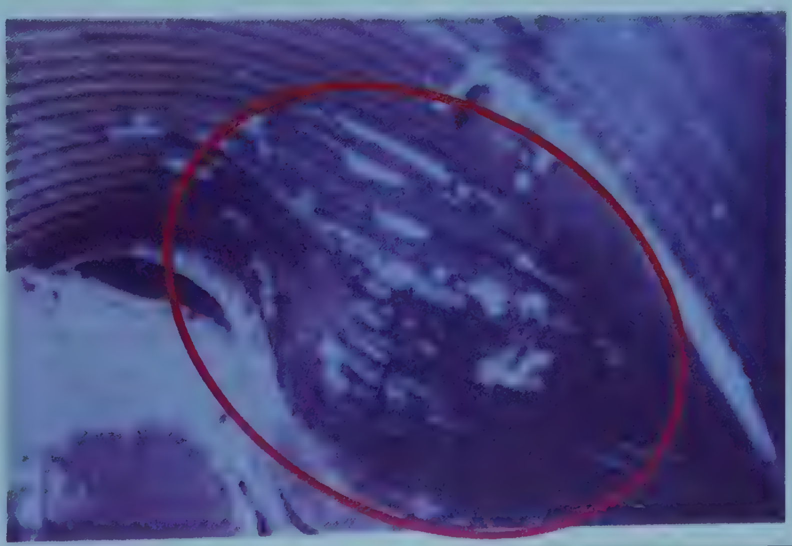


Remarkable lowering of drainage function (Ranking A)

Lowering of drainage function (Ranking B)

[16]

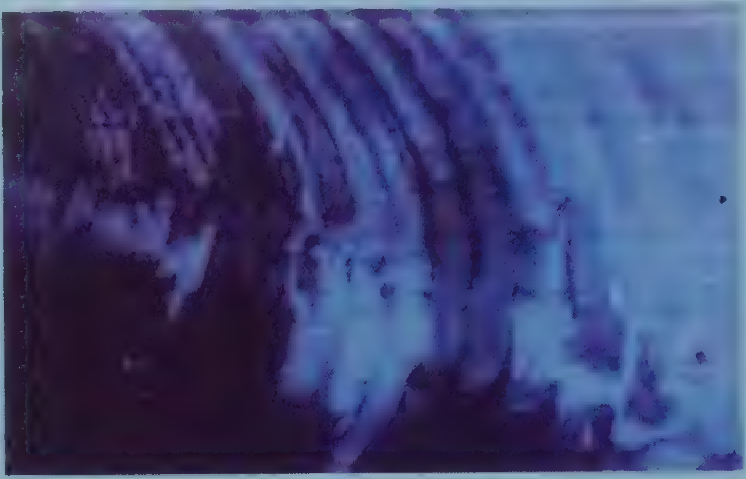
Figure 5-81: Silting



Large deformation of a culvert

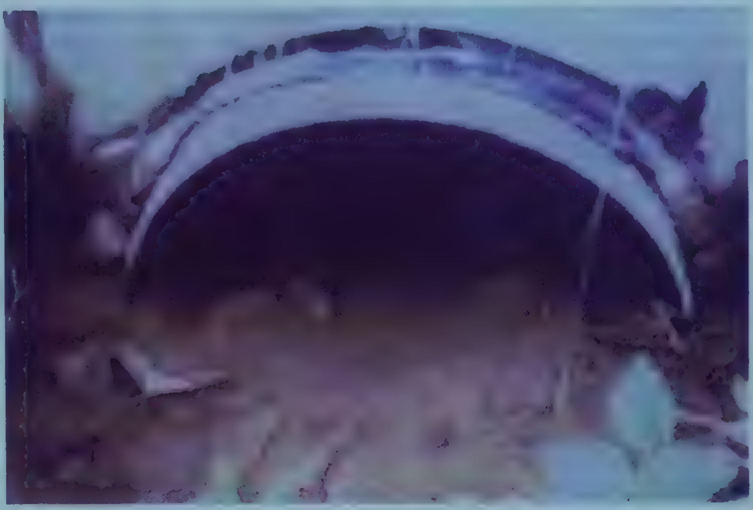
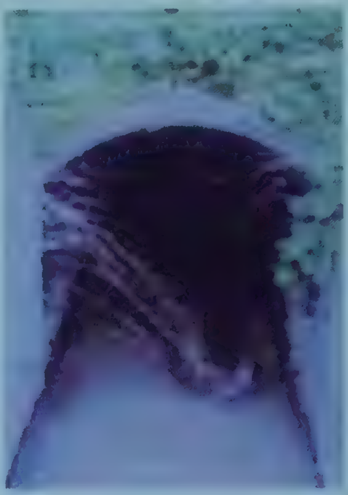
[16]

Figure 5-82: Damage of Culvert (Ranking A)

Partial Corrosion


[16]

Figure 5-83: Partial Corrosion of Culvert (Ranking B)

Remarkable lowering of drainage function (Ranking A)	Lowering of drainage function (Ranking B)
	

[16]

Figure 5-84: Silting of Culvert

5.10 Detailed Investigation

A detailed investigation is conducted based on an inspection result, with an aim of obtaining necessary information to check the function of structure as well as selection/review of appropriate countermeasure method. An investigation includes checking the deformation or damage, specific soundness of a structure as well as figuring out the causes of defects by collecting information other than inspection records and thereafter selecting and reviewing an appropriate countermeasure. Purpose of investigation depends on the condition or type of a target structure, as below;

1) Detailed Investigation to Understand Current Status

This type of detailed investigation aims to understand quantitatively the current damage condition or damage progress of structure (location, form, degree, etc.), based on observation or measurement taken on site. Comprehensive evaluations on obtained investigation results and studies on the necessity of repairing or renewing targeted structures are also conducted. Where necessary, causes of damages are examined and thus prolonged countermeasures are studied.

2) Detailed Investigation to Understand the Detail of Damage and Cause

An inspection is sometimes insufficient to evaluate the soundness of ground anchor or slope stability. This item aims to conduct a detailed investigation on slope structure in a quantitative manner. If reinforcement work is deemed necessary to secure the safety of a structure, relevant data shall be obtained through this investigation to study possible countermeasures.

5.10.1 A mindset of Detailed Investigation

In general, earth structures have various factors or causes of deformation according to their respective design/construction, climate, or traffic. In this regard, an appropriate investigation result is not necessarily obtained by a single investigation method. When a detailed investigation is conducted while the deformation of the structure continues, prompt countermeasures may be conducted, if necessary, according to a status even in the middle of the investigation. For planning and implementation of an investigation, each site situation shall be flexibly considered, with paying attention to the following basic principles.

1) Prior to the planning of an investigation, it is important to collect, organize, and analyze necessary data, such as past inspection/investigation records of a target structure, disaster history, or records related to maintenance/reinforcement. In addition, records at the time of construction may become an important clue to evaluate the soundness of an existing structure.
2) Proper methods and scope should be selected based on an overall investigation plan which is compiled prior to the actual investigation. Because an earth structure has a nature to suffer similar symptoms in an adjacent area, it is recommended to check topography/geography by relevant DPR reports and determine the most appropriate sections and scopes of investigation.
3) The investigation shall be systematic and effective by eliminating improper works according to the degree of importance. In particular, if a past record or data at the time of construction is available, such data shall be utilized. Moreover, the scope of investigation shall be examined by taking account of future countermeasures and follow-up investigations.
4) When deformation of the structure is likely to happen by multiple causes, various investigations shall be needed. If investigations are started with an easygoing attitude, it might lead to an unfavorable situation in which a responsible engineer may realize additional investigation is necessary at the time of using the investigated data. Therefore, it is important to understand exactly what investigations are for and take an adequate review. Even in the course of investigations, it is recommended to understand intermediate results. In case it is identified that an initial plan is unable to achieve its original purpose, flexible actions should be taken, such as rescheduling the initial plan.
5) It is important to understand any changes in the situation of the surrounding environment in addition to the topography, geography, weather, and traffic condition of a target area. In addition, it is favorable to consider the necessity of safety arrangement and traffic regulation during an investigation, as well as mobilization route, transport method, and temporary structure of necessary equipment.

5.10.2 Basic Procedures

Based on the past experience, there are efficient and basic procedures for detailed investigation, which are 1) through 3) below:

1) Desk research shall be performed to collect fundamental information of the construction phase in addition to existing documents such as past inspection results or maintenance/repair history of a target structure. It is preferable to conduct an efficient investigation by extracting and organizing required items for evaluations or countermeasure works through both on-site reconnaissance and desk research.
2) The on-site investigation needs to be conducted in appropriate methods and scale based on each purpose; therefore, it shall be performed considering an adaptable range of each equipment by reflecting the current situation. In the maintenance stage, the on-site investigation is conducted on a road in service with traffic regulation in many cases. Therefore, it is necessary to pay attention to the constrained condition when planning a work program. When follow-up investigations are required after deformation or repair/reinforcing of structure due to landslide, investigation schedule shall be considered.
3) In order not to have discontinuous investigation or deficiency of investigation, it is important to fully understand previous investigation results and remaining issues. As for compiling results of follow-up investigation, it is recommended to report facts revealed by an investigation on an as-needed basis and to prepare a plan for subsequent follow-up investigation, if any.

5.10.3 Detailed Investigation of Cut and Embankment

The detailed investigation of cut and embankment shall be performed under proper emergent measures when traffic or a third party may be affected by collapse or possible collapse. Investigation of cut/embankment is conducted not only at a time of a collapse, but also when sudden progress is observed after small deformation, when deformation is noted after repairing/reinforcing, or when cracks continue to exist at the location where stability analysis is required.

When deformation happens on cut/ embankment, possible causes are classified into two elements, which are “physical factor (geography, soil, topography, etc.) and “environmental factor (weather condition, weathering, earthquake, etc.)”. In general, it is difficult to solve a deformation mechanism clearly unless causes of deformation are taken accurately. Therefore, it is important to consider multiple factors of information for the evaluation of the cut/embankment.

(1) Basic Approach to Detailed Investigation of Cut Slope

For the detailed investigation of the cut slope, it should be kept in mind that destabilization of the cut slope progresses over time.

- ✓ The stabilization of the cut is realized by a balance between sliding force by gravity and resistance force by ground or structure. This balance is related to multiple elements such as topography, geography, soil, underground water, materials, and slope structures, which mechanism is very complicated.
- ✓ Earth structure has a nature to deteriorate over time.
- ✓ The cut slope is easily affected by an external force, including heavy rain and earthquake.

Based on the above points, it is important to develop an investigation plan and evaluate the result after understanding of cut slope condition in detail and recognizing the progression of deterioration over time. Additionally, It is important to acquire related knowledge of landslide or slope failure, which enables to prevent or minimize a disaster beforehand by predicting possible influence on highways in advance.

(2) Basic Approach to Detailed Investigation of Embankment

Embankment structure typically has a nature that a location with a problem in a construction phase has a problem in a maintenance stage also. While embankment tends to gain its strength over time depending on the soil material used, some embankment loses their strength by the property of slaking on the other hand. Therefore, it is necessary to understand the characteristic of embankment material. When the longitudinal direction of crack is identified on the pavement of embankment, careful attention needs to be paid to potential sliding, which may be caused by seepage water from rainfall. In particular, when a crack is repeatedly observed after pavement surface treatment, it is advisable to investigate in detail

5.10.4 Detailed Investigation of Cut Slope

(1) Objective and Item

Detailed investigation on cut slope aims to identify a failure mode and causes as well as to obtain data and materials for the design of countermeasures. Major investigation items are as follows;

1) Condition of deformation

- ✓ Horizontal range of areas where slope failure may occur
- ✓ Depth of slip surface, the shape of a cross-section
- ✓ Stability of unaffected slope, presence of cracks, etc.

2) Cause of deformation; study of the above items should be considered as well.

- ✓ Causes in the past cases, which were determined as major causes
- ✓ Deformation form of the slope with similar soil properties, which occurred in a different place
- ✓ Soil properties (cohesion, internal friction angle, unit weight of slip soil mass)
- ✓ Groundwater level, strata

3) Progress of deformation

- ✓ It is important to check the amount of slope deformation when it rains and underwater level changes.

4) Condition of countermeasure work

- ✓ In case countermeasure work is already placed to stabilize a concerned slope, it is necessary to understand the contents of its existing design. In addition, it is recommended to compare parameters used for the design and those obtained through investigation.

(2) Method of Detailed Investigation

This subsection explains typical investigation methods. Depending on the condition of a phenomenon, a suitable investigation method should be adapted.

1) Detailed Investigation on Existing Document

The existing document is examined to examine the information at the time of construction, which includes the following;

- ✓ Soil test results
- ✓ Information on design and construction
- ✓ Geography
- ✓ Topography
- ✓ Slope structure (slope gradient, number of berms, berm width, etc.)
- ✓ Underground structures
- ✓ Underground facilities

In case inspection and/or repair works are performed on a concerned slope, relevant records shall be examined as well.

2) Detailed Investigation on Weather

In general, rainfall or snowfall is a major contributor to the deformation of the slope. Therefore, weather data shall be examined, which is obtained at public weather stations adjacent to a concerned highway or dedicated weather stations operated by a highway operator.

3) Detailed Investigation on Site

Detailed Investigation on-site should be performed not only for a spot where deformation is visible but also for a whole slope, upper slope, road surface, retaining wall, drainage structures. Investigation results shall be compiled in the form of a sketch, figure, photographs, etc.

4) Measurement on Ground Surface Displacement

This measurement aims to identify how active a concerned slope is. It measures changes in cracks on the ground surface over time. Following methods are typically used in consideration of local conditions.

- ✓ Measurement by Batten / Stake
- ✓ Land survey with a total station
- ✓ Ground surface inclinometer
- ✓ Extensometer
- ✓ GNSS
- ✓ Aerial laser survey

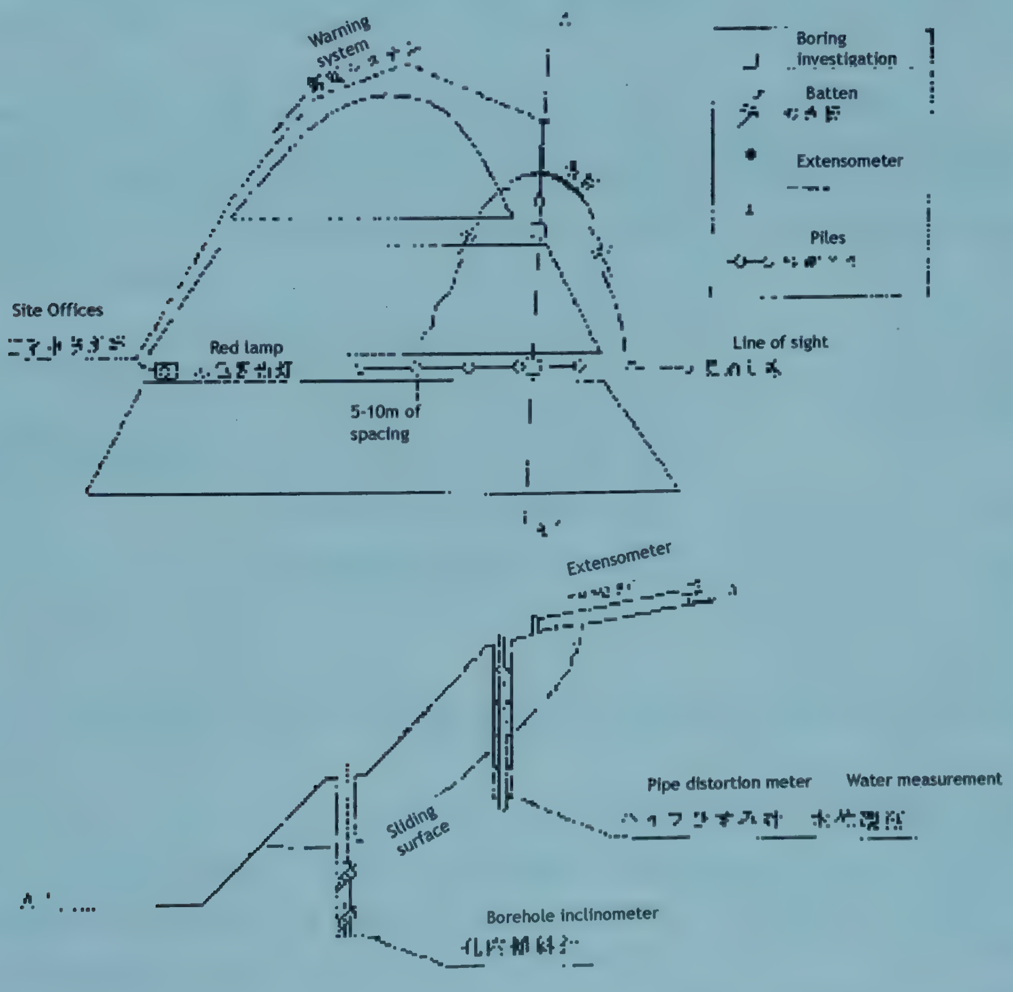
5) Boring Investigation

The boring investigation is performed to determine the depth of slip surface and ground conditions (e.g. strata, underground water level, N-value). It is preferable to perform more than two borings per survey line within the range of deformation. In addition, it is recommended to set multiple survey lines according to the scale of deformation. The boring investigation shall be done as all-core drilling and logging as far as possible. When soft rock is adapted as bedrock, a standard penetration test (SPT) is performed every 1m and other sections are often drilled as all-core boring. A borehole is utilized for monitoring purposes by such as borehole inclinometer, pipe strain gauge, underground water monitoring, etc. Boring core samples shall be visually inspected in a careful manner to confirm sample disturbance, presence of clay layer, color tone, presence of slickenside, etc., from which, strata and depth of slip surface are determined. In addition, a direct shear test or triaxle compression test is performed for the core samples from the slip surface as needed, which derives sliding surface strength. When mudstone is found on the ground of cut slope, stress release might be the possible cause of land sliding and thus, a laboratory test to confirm rock swelling property is conducted where necessary. It should be paid attention that slip surface strength obtained by laboratory tests sometimes does not represent a whole strength of sliding mass. In order to design countermeasure works, a bore-hole horizontal loading test shall be performed at the same time with the boring investigation as necessary.

6) Underground Displacement Measurement

Underground displacement measurement is performed to understand the depth of the slip surface and how active a concerned slope is. Figure 5-85 shows an example of the arrangement of measurement equipment. The followings are typical measurement equipment, which shall be applied in consideration of each local condition.

- ✓ Borehole inclinometer (install-type)
- ✓ Borehole inclinometer (insert-type)
- ✓ Pipe strain gauge
- ✓ In-place extensometer/multi-layer in-place extensometer



[17]

Figure 5-85: Investigation of Hazard Area / Instrument Arrangement (Cut Slope)

7) Groundwater Level Monitoring

Groundwater level monitoring is performed by using a borehole. The observation is conducted by hands using stylus type water-level gauge or continuous measurement by placing self-recording water-level gauge. It makes it easier to understand the actual deformation of a slope by organizing a relationship among the amount of rainfall, groundwater level, and slope displacement.

8) Laboratory Soil Test

For the reinforcement work of the existing embankment, a laboratory soil test should be performed to understand the soil property, parameters for design, etc. Necessary soil tests should be conducted from the list of soil tests, shown in Table 5-41 below, taking account of each local condition and inspection results.

Table 5-41: Major Items for Geological Test for Existing Embankment

Test method	Investigation contents
Density test of soil particle, Wet density test, Water content test, Grain size analysis, Liquid, and plastic limit test	The soil particle density of cut and embankment, Water content, etc.
Triaxial compression test	Strength of cut and embankment material, etc.

[17]

9) Investigation on Surrounding Environment

Detailed investigation on the surrounding environment is performed to understand the facilities, environment, traffic, construction yard, etc. Table 5-42 shows the items for investigation on the surrounding environment. The necessary investigation shall be selected according to the situation, taking into account such inspection results.

Table 5-42: Major Items for Surrounding Environment Investigation

Items for investigation	Contents of detailed investigation
Surrounding facility	Types of structure and underground facility lines, Distance between, etc.
Surrounding environment	Water usage condition, Environmental constraints, Noise and vibration restriction, Vehicle entry restriction, Working time restriction, etc.
Road in service	Daily traffic, Number of lanes, Lane restrictions, etc.
Construction site	Presence of service road, wide berm, and construction vehicle route Location of the construction vehicle entrance from the main line Equipment/material loading method Availability of water and electricity

[17]

5.10.5 Detailed Investigation of Slope Protection by Vegetation

(1) Objective and Item

Detailed investigation on a vegetated slope is performed on a location where vegetation on the slope is deteriorating and affecting embankment and/or cut slope body. The investigation is conducted to identify the status of vegetation degradation and driving factors and thereafter to obtain relevant data to perform countermeasure of maintenance/rehabilitation by protection measures.

Investigation on vegetation is performed to understand vegetation degradation that may possibly lead to collapse, the exuberance of hydrophilic plant or softness of slope, etc. The major items for investigation on vegetation slope are as follows;

1) Vegetation

- ✓ Tree fall/lean: Fall of tree or lean, etc.
- ✓ Withered plant: Range where declination/withered plant is observed in vegetation
- ✓ The exuberance of hydrophilic plant: Range where the exuberance of hydrophilic plant is observed.

2) Ground surface

- ✓ Spring water: spring water spot and amount of spring water
- ✓ Condition of ground surface: Deformation area such as gully erosion

3) Amount of spring water

- ✓ A drainage system is particularly important in vegetated slopes. It is necessary to evaluate the amount of spring water precisely.
- ✓ Around the area where spring water is observed, it is important to perform a close investigation on-site in order to understand the area of spring water, condition of the hinterland, amount of water spring, etc.

(2) Method of Detailed Investigation

The principal investigation method is to focus on a time change of vegetation. The on-site investigation should identify the exuberance of weeds, lack of fertilizer, type/scale of deformation due to sediment discharge, etc., the results of which shall be organized as a plan view and developed view. In case past data on vegetation conditions is available, such material should be organized to understand the progression of degradation. A result of the investigation shows the necessity to follow up and evaluate the degradation, an area, monitoring items, and method shall be organized for the follow-up investigation.

5.10.6 Detailed Investigation of Shotcrete

(1) Purpose and Objective

Detailed investigation on shotcrete is performed when progress in deformation is observed on a sprayed slope, which is considered a decline in protection function such as weathering inhibition of ground. Investigation on a sprayed slope, in addition, is performed to obtain necessary data for countermeasures of maintenance/ reinforcement as well as identifying the form and cause of deformation on a sprayed slope.

The deformation of the sprayed slope is classified into two types; one occurs on the surface of the spayed slope, and the other on the upper slope of the spayed slope. Investigation on the surface of sprayed slope should focus on the possibility of strength reduction of ground, earth pressure act by collapse or possible landslide, for which desk research should be conducted, where necessary, along with site investigation. Investigation on deformation on the upper slope, on the other hand, should focus on edge of spraying or drainage, trace-based on drip holes. Possible cause of deformation includes deformation of upper slope, supply of water, etc.

It is important to determine the form of deformation, the relationship among driving factors in order to obtain proper data for repair work and countermeasures. A major role of the sprayed slope is to prevent weathering of the ground; therefore, a relevant investigation shall be referred additionally if countermeasure for slope failure or landslide is necessary.

It is necessary to select proper investigation item(s) which can reveal the cause of deformation or and provide data for countermeasures. Investigation items for sprayed slope are classified into “deterioration or damage of shotcrete itself”, “the adhesion of shotcrete and the back surface of the ground” and “deformation of erosion on the back surface of the ground”.

1) Deterioration or damage of shotcrete

Cement mortar and concrete spraying are aging over time. The causes of aging are possibly freezing damage, neutralization, salt damage, etc. Major deformations are crack, spalling, strength reduction, etc.

2) Adhesion of spray and the back surface of the ground

The adhesion strength between shotcrete and the ground surface underneath the shotcrete sometimes decreases, which leads to the sliding of shotcrete due to gravity force.

In addition, a cavity is likely to appear on the back surface because of flowing out of weathered sand/rock in the following cases:

- where spring water is present on the back surface of ground of spraying, and proper treatment is not conducted, including underground drainage
- where drainage failure occurs due to blockage of drain hole with mud, garbage, weed, etc.

3) Erosion of upper slope

In case ground pressure on a sprayed slope increases due to the erosion on an upper slope, cracks and/or deformation on the sprayed slope are sometimes induced. When it is judged that the scale of deformation on an upper slope is very large and the slope is unstable, additional slope investigation and investigation on landslides are required.

(2) Detailed Investigation Method

The detailed investigation method of the sprayed slope is as follows;

1) Detailed Investigation on Spraying

Investigation on spraying is performed to measure crack, displacement measurement such as joint opening, and to confirm the degree of aging on cement mortar spraying as well as shotcrete by intensity test done by coring. Investigation on adhesion strength between shotcrete and ground beneath the shotcrete is performed by hammering test or thermal infrared image that enables to judge condition in a wide area without touching or destroying shotcrete. Results of the investigation reveal the range and spots where deformation is progressed. Adhesion strength is further confirmed by core sampling and drilling investigation for these locations.

2) Detailed investigation to Confirm Ground Condition

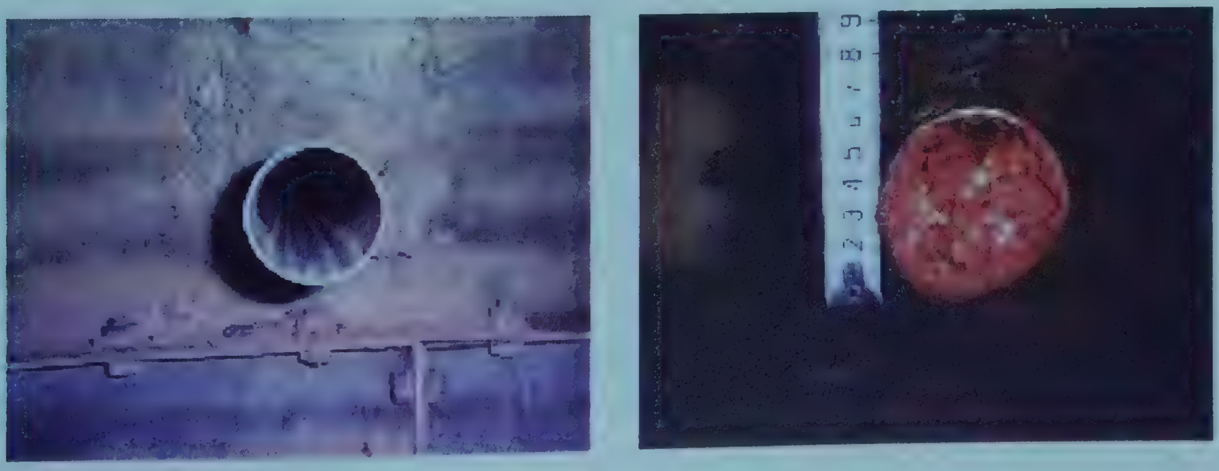
Subsurface condition of background is often a driving factor of deformation on the sprayed slope. Depending on weathering property, stratum such as dip slope or plunging slope structure, underground water distribution, etc., cavity possibly progresses due to drain out of back soil. Therefore, when deformation occurs, it is important to investigate the background condition, not only the condition of the shotcrete. In case ground pressure from the background or large sliding mass is a possible cause, slope stability analysis should be conducted through investigation on the slope and landslide mass. Location of drilling investigation should be determined by taking account of the location of survey line(s), based on which stability analysis and monitoring are conducted.

5.10.7 Detailed Investigation of Horizontal Drainage Boring

(1) Purpose of Detailed Investigation

When any blockage is formed in a horizontal drainage boring, a concerned slope possibly becomes unstable due to an increase in groundwater pressure. Proper inspection and investigation shall be conducted to identify driving factors of the blockage and thereafter to conduct countermeasures, including recovery of water passing function by cleaning or placing of additional drainage borings. Inspectors should pay attention to the following points:

- ✓ It is advisable to confirm whether any deformation is identified on a concerned slope due to an increase in groundwater pressure. As shown in Figure 5-86, it is important to confirm the condition of blockage and the amount of drained water over time.
- ✓ Type, scale, and location of deformation shall be confirmed, and an on-site survey shall be performed for surrounding facilities, upper slope, etc.
- ✓ It is preferable to inspect surrounding drainage systems.
- ✓ As shown in the right side picture of Figure 5-86, where a scale adhesion is observed on a drainage hole, it is required to perform a water quality survey to identify possible causes, based on which suitable cleaning frequency for drainage boring is studied.



[17]

Figure 5-86: Example of Unclogged Drainage (left) and Clogged Drainage(right)

(2) Method of Detailed Investigation

The condition of horizontal drainage boring is generally influenced by rainfall or underground water; hence, it requires paying attention to the weather or season when the on-site inspection is conducted. The followings are major items when performing drainage boring investigations.

1) Inspection on Blockage Position

Inspectors shall check the drilling length of drainage in advance by desk research, and then conduct inspection on-site to confirm whether the measuring bar can insert and reach the end point of the drilling. Inserting the measurement bar into each drilling hole can reveal the location of the blockage.

2) Inspection of the Amount of Drainage

Short-term observation of drainage amount shall be measured by each hole using a measuring cup or measuring cylinder. Not only from the drainage tube, but the location between the tube and borehole wall or around the hole shall be measured together, if any. Results on these measurements shall be recorded.

Long-term observation of drainage amount shall be conducted by installing an automatic observation device in order to measure drainage volume continuously. Continuous measurement of drained water volume is performed to confirm if there is any correlation between rainfall and drained water volume as well as seasonal changes of the volume. When cleaning of drainage hole is performed, drainage volume before and after the work shall be performed.

5.10.8 Detailed Investigation of Drainage Well

(1) Purpose and Item

A drainage well is typically constructed to drain deep groundwater out and thus decrease groundwater level as a stabilization of the landslide. Investigation of drainage well is performed with the purpose of obtaining data and material of damage or deformation, based on which cleaning or additional collecting boreholes are to be conducted to recover the original function of drainage well.

1) It is necessary to confirm whether the water passing function has not been blocked by sediment such as soil. As shown in Figure 5-87, the damaged area of the drainage well includes the well structure, collecting boreholes, discharge borehole, canopy, etc. The well structure sometimes has a damage/deformation of its body or discharge borehole, leading to waterlogging. In addition, failure is mostly seen in collecting boreholes, including adhesion of scale or corrosion of the steel tube. The major failures of drainage well are as follows;
    - ✓ Damage of collecting/discharge boreholes, associated with deformation
    - ✓ Abnormal waterlogging
    - ✓ Impediment of water passing through collecting boreholes due to adhesion of scale
2) When blockage or deformation occurs in collecting boreholes, a concerned slope sometimes becomes unstable due to decreased drainage function. Therefore, sufficient investigation shall be performed to identify the causes of such failures

in order to realize recovery of water passing function by cleaning or installing additional collecting / discharge boreholes.

3) The followings are the major items for the investigation of drainage well;
   - ✓ Deformation of drainage well (fence, canopy, well structure)
   - ✓ Abnormal waterlogging
   - ✓ Water passing function of collecting boreholes

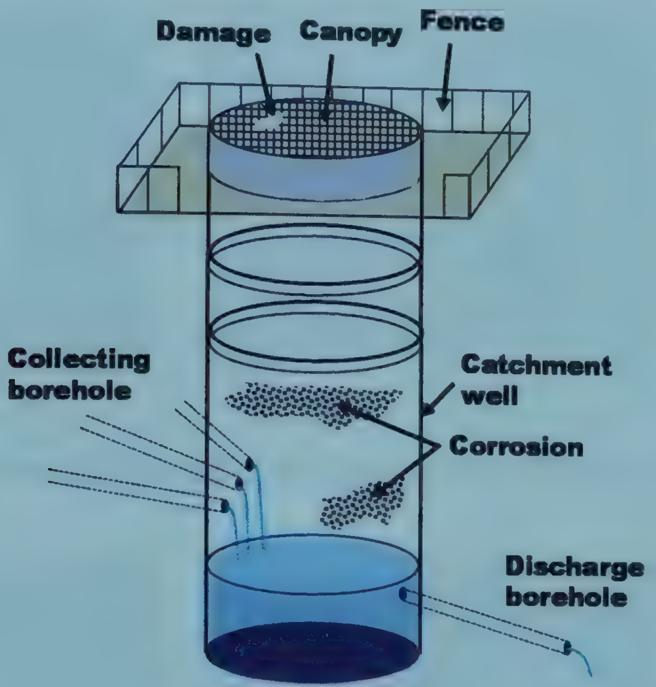


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Figure 5-87: Inspection Area of Drainage Well

(2) Detailed Investigation Method

Past experiences suggest major investigation points, as follows;

1) Corrosion and deformation

A drainage well made by a liner plate tends to be susceptible to corrosion incurred by highly acidic water.

2) The water level in the drainage well

Because the water level in the drainage well is generally influenced by rainfall or underground water, it requires paying attention to the weather or season when an investigation is conducted. In order to take into account these factors, it is recommended to record and study the volume of drained water over time.

3) Water passing function of collecting borehole

It is recommended to refer to the section of horizontal drainage boring in this guideline for the function of collecting borehole.

5.10.9 Detailed Investigation of Ground Anchor

(1) Purpose and Item

Detailed investigation of ground anchor (hereinafter referred as to "anchor") is performed with the purpose of obtaining material and data to conduct planned maintenance/reinforcement or appropriate inspection/investigation of the anchor after identifying the specific cause of deformation as well as to understand the exact condition of the abnormal anchor. Anchor is basically constructed on an unstable cut slope. It is important to understand the exact condition of each anchor, the soundness of the anchor system, as well as safety of a concerned slope because the risk of an unstable slope can pose a threat to safe and smooth traffic. Figure 5-88 and Figure 5-89 show examples of deformation of anchor head, and it is easy to detect by general inspection of slope surface.

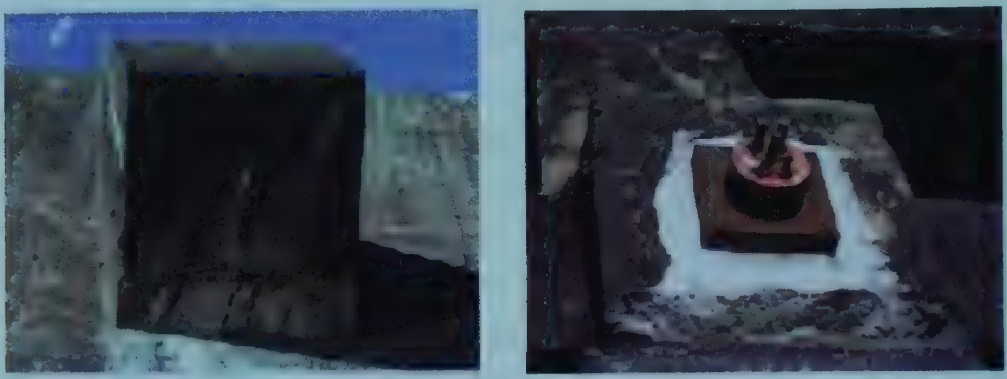

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Figure 5-88: Head of Concrete (Left) and Corrosion of Anchor Head (Right)

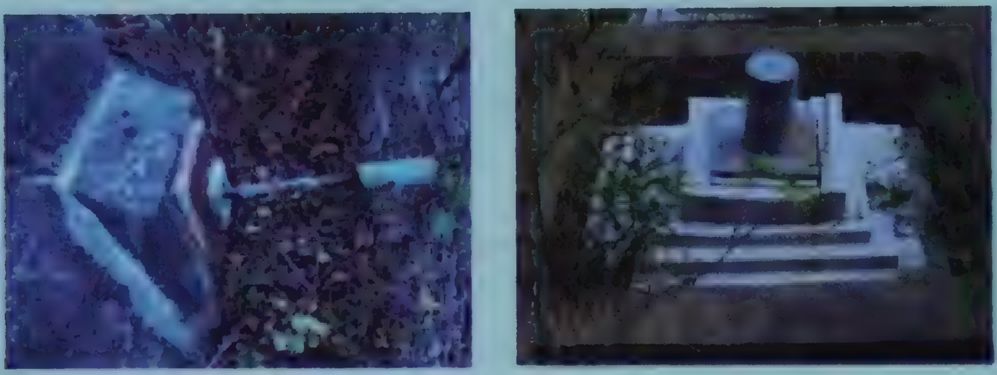

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Figure 5-89: Steel Anchor Sticking Out (Left) and Deformation of Pillow (Right)

Detailed investigation of the anchor is performed for a slope in which soundness should be checked in consideration of slope inspection results.

Anchor investigation includes 1) detailed visual observation of the appearance of anchor head, 2) detailed visual observation of anchor head (corrosion condition, setting condition, rupturing/damage, comparison with the previous investigation, etc.) by removing protective cover of the head, and 3) confirmation of the performance of anchor or remaining tension by introducing tensioning force. Data and materials obtained through the above investigation shall be organized and documented to determine whether a concerned anchor system is functioning soundly or its slope surface is stable. The followings are the major items of investigation on soundness.

1) Detailed Visual Investigation of the Head

This investigation aims to visually observe the anchor head in detail including protection cover. If necessary, a hammering test is performed together.

2) Detailed Visual Investigation of the Head by removing protection cover

This investigation removes the protection cover very carefully and then makes a detailed observation on the condition of anchorage components and tendon parts. A hammering test is performed, when required. After a series of investigations, a protection cover shall be placed over the anchor head to prevent the progress of corrosion.

3) Lift-off Test

- A lift-off test is performed to confirm the remaining tension of an anchor by placing a hydraulic jack on an anchor head. Depending on the condition of an anchor, an abnormality may arise, such as fracture of anchorage before reaching a maximum test load. Therefore, the test should be carefully conducted by paying attention to the ongoing load-displacement relationship and by checking if there is any unfavorable situation, such as abnormal sound or vibration.

4) Performance Verification Test

Performance verification test is performed to check if an anchor keeps intended drawing tension and binding force, in case degraded soundness of anchor by a failure of the anchor body is identified by an inspection. The test is conducted by loading staging of multiple cycles (generally 5 cycles) to design anchor force after releasing the tension. The performance of the anchor is judged by the measurement results of the load and deformation.

5) Load Measurement

Load measurement is performed to measure applied tension by a load meter installed on an anchor head.

(2) Method of Detailed Investigation

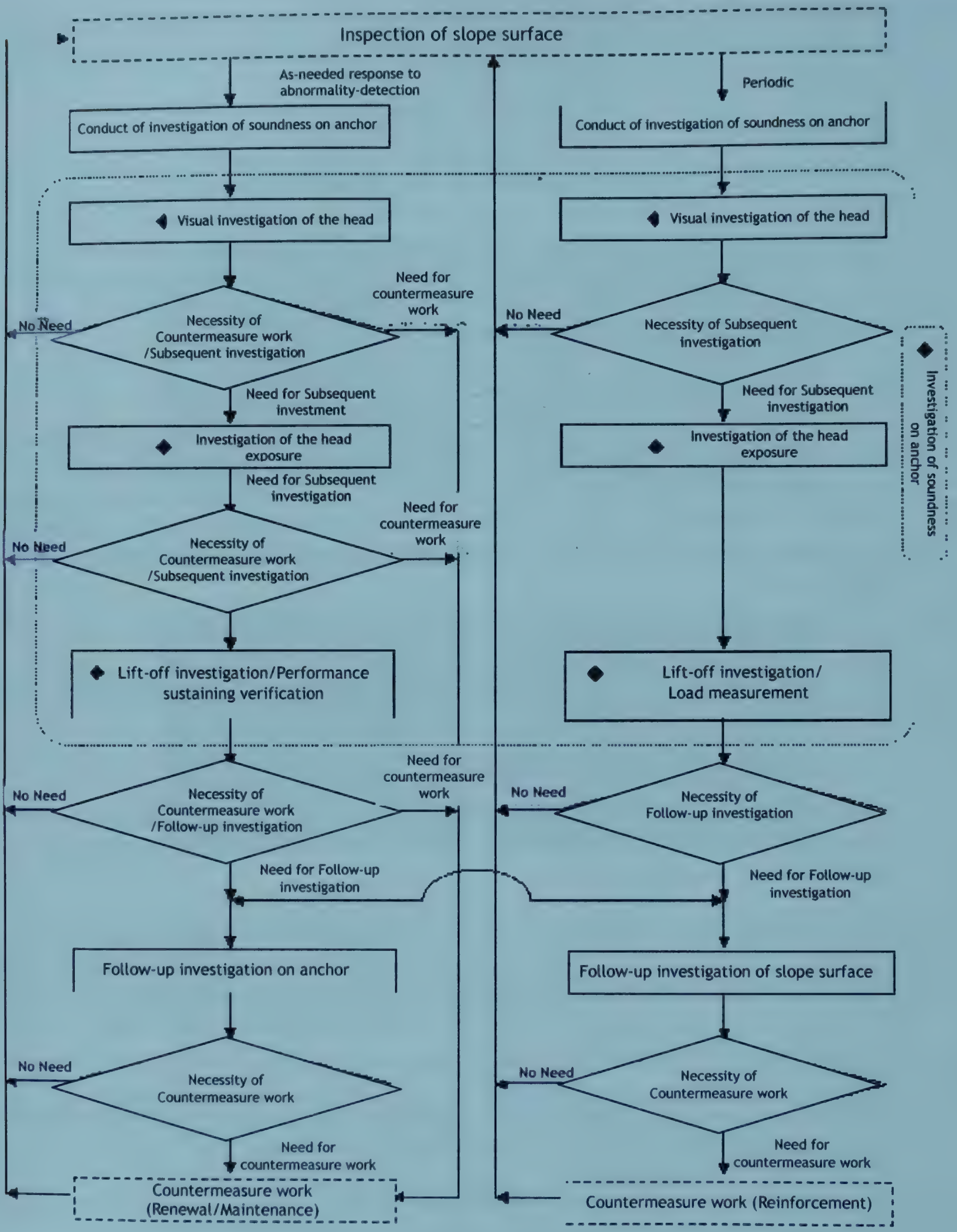
Detailed investigation of anchor includes “detailed visual investigation of the head”, “detailed visual investigation of the head by removing protection cover” and “performance investigation”.

The soundness of an anchor is firstly investigated by a detailed visual investigation of the head and then, a detailed visual investigation of the head by removing the protective cover is performed, if necessary. Based on the results of these investigations, lift-off tests or performance verification tests are performed, when it is necessary to confirm the performance of an anchor(s).

The range or area of follow-up investigation shall be determined by studying all past investigation results. Follow-up investigation includes the investigation to understand further detail of the anchor itself and the investigation to understand the stability of a concerned slope. A proper investigation method shall be selected by considering the purpose and method of each investigation.

When a follow-up investigation is performed, the necessity of countermeasure work is studied based on the results of the investigation. In case an abnormal anchor is detected, it is preferable to perform periodic investigation conducted for a concerned slope, as necessary.

The flow of soundness investigation is shown in Figure 5-90.


Inspection of slope surface
As-needed response to abnormality-detection
Periodic
Conduct of investigation of soundness on anchor
Conduct of investigation of soundness on anchor
Visual investigation of the head
Visual investigation of the head
Need for countermeasure work
No Need
Necessity of Countermeasure work /Subsequent investigation
No Need
Necessity of Subsequent investigation
Need for Subsequent investment
Need for Subsequent investigation
Investigation of the head exposure
Investigation of the head exposure
Investigation of soundness on anchor
Need for Subsequent investigation
Need for countermeasure work
No Need
Necessity of Countermeasure work /Subsequent investigation
Lift-off investigation/Performance sustaining verification
Lift-off investigation/ Load measurement
Need for countermeasure work
No Need
Necessity of Countermeasure work /Follow-up investigation
No Need
Necessity of Follow-up investigation
Need for Follow-up investigation
Need for Follow-up investigation
Follow-up investigation on anchor
Follow-up investigation of slope surface
No Need
Necessity of Countermeasure work
No Need
Necessity of Countermeasure work
Need for countermeasure work
Need for countermeasure work
Countermeasure work (Renewal/Maintenance)
Countermeasure work (Reinforcement)

[17]

Figure 5-90: Investigation Flow of Soundness

5.10.10 Detailed Investigation of Retaining Wall

A detailed investigation shall be conducted to detect driving factors of progressing damage on a retaining wall structure or surrounding structures. It shall be also performed when sliding, tilting, the collapse of a retaining wall is concerned.

The investigation aims to obtain the required fundamental material and data to design an appropriate countermeasure work through a proper understanding of the cause of deformation. Results of the investigation shall be organized so that they are effectively used in the later maintenance period.

The type of retaining wall includes gravity retaining wall, cantilever wall, reinforced earth wall, or retaining wall with lighter weight materials.

(1) Purpose and Item

Detailed investigation on the concrete retaining wall is performed when progression in deformation is observed or when it requires to confirm the stability of the retaining wall. It also aims to obtain necessary data and material for identifying the cause of deformation and then planning and design maintenance/reinforcement countermeasures. The followings are the major items of detailed investigation.

1) Deformation of Concreate Retaining Wall

It is important to confirm the presence of a crack leading to collapse, deformation, or tilting of a wall, etc. In case substantial settlement, movement, tilting, or step-formed deformation of background which may lead to the collapse of retaining wall is identified, it is necessary to confirm the causes of these deformations.

2) Abnormal Springwater

Malfunction of roadside drainage or slope drainage system allows infiltration of rainwater into the back-filling part and then causes deformation of retaining wall due to loosened back-filling and increased earth pressure. In order to maintain the stability of the retaining wall, it is important to confirm causes of deformation such as changes in drained water volume or degraded function in the drainage system when significant spring water or its trace is confirmed from a drain hole or a joint.

3) Deformation of Foundation Ground

Penetration is attached to the base of the concrete retaining wall to minimize the negative influence by scouring or digging action. When scour is obviously observed on a foundation or the wall body, deformation sometimes occurs.

(2) Detailed Investigation Method

This subchapter explains major investigation methods for a concreate retaining wall. Proper methods shall be selected according to a symptom identified on the concrete retaining wall.

1) Investigation of displacement of concrete retaining wall

This investigation aims to reveal the possibility of progression of tilting, settlement, or cracking by measuring the displacement or width of the crack. When deformation of retaining wall is confirmed, driving factors shall be determined through making a judgement for each classification of inner factors (e.g. problem of design or construction) and external factors (e.g. rainfall, earthquake). When it is difficult to identify driving factors even by referring to past records at the time of construction or past inspection results, implementation of follow-up investigation shall be examined.

In case a retaining wall is judged unstable with the evidence of failure by lateral cracks, joint displacement due to uneven settlement, push-out due to lateral movement or tilting, it is preferable to investigate not only for a concerned wall but also for embankment/cut slope body and road surface.

2) Investigation on the cause of spring water

Investigation on spring water includes confirmation on the trace of surface water infiltration into the ground, failure of the drainage system, and measurement of groundwater level. It is preferable to confirm if there is any depression behind the retaining wall. If depression is observed, follow-up monitoring including the surrounding of a retaining wall is recommended.

3) Investigation on the cause of deformation on foundation ground

When deformation due to lack of bearing capacity on the fundamental ground is considered, it is recommended to investigate the status of deformation and conduct a geotechnical investigation.

5.10.11 Detailed Investigation of Reinforced Earth Wall

(1) Purpose and Item

When deformation of retaining wall body shows a tendency of progressing or when a crack occurs on the surrounding of retaining wall and its stability is concerned, a detailed investigation shall be performed in order to obtain material and data to perform maintenance/reinforcement countermeasure.

In regard to investigating reinforced earth walls, the following points should be taken into account;

1) It is necessary to fully understand the characteristic of reinforced earth walls, including that it is a flexible structure to allow displacement to some degree.
2) Detailed investigation of reinforced earth wall firstly starts with site investigation to confirm the type, scale, and location of the deformation of the wall, then surrounding ground, structures, as well as upper slope. Subsequently, an investigation on displacement to understand the deformation of reinforced earth walls shall be performed.
3) It is necessary to understand the progression of deformation to judge if repair work is necessary only on the wall surface.
4) If a dedicated device becomes necessary for the detailed investigation, well-experienced professional engineers are needed for handling such a device. The Schedule of work shall be also well examined.

The followings are the major investigation items of reinforced earth wall;

- ✓ Deformation of wall surface
- ✓ Pull-out strength of reinforcing material
- ✓ Deformation of foundation ground

Properties of embankment material, presence of spring water, and groundwater level are sometimes important for understanding the deformation of the reinforced earth wall. According to the circumstances, detailed investigation such as geotechnical investigation or pull-out test of reinforcing material is likely to be performed. When the back-filling material, foundation ground, surrounding bedrock, etc. is assumed to be the cause of deformation on reinforced earth wall, it is necessary to select an appropriate investigation method, range, etc. Therefore, judgement done by engineers with a certain level of special knowledge, experience, etc. is needed.

(2) Detailed Investigation Method

A detailed investigation is firstly conducted by desk research including previous literature or inspection history data, reconnaissance on surrounding areas, as well as the survey by measuring displacement or relevant structures. Based on these results and measured displacement, the deformation causes shall be estimated. Secondary, detailed investigation shall be selected for each estimated cause, and then a detail investigation shall be performed.

As for the displacement investigation, it enables us to understand the progression of deformation by setting a fixed control point. When loosened, heaving, depression, or movement is found on a reinforced earth wall, a fixed control point shall be set to understand the progression of the deformation.

The following are major investigation methods for reinforced earth walls and important points for the investigation methods.

1) Investigation of Wall Surface

Detailed investigation of displacement shall be performed to confirm the progression in deformation of reinforced earth wall as well as the surrounding structure, which is earlier confirmed by inspection. It shall be kept in mind that this investigation has limitations to determine corrosion condition of the connecting part between reinforcing material and wall surface material and thus, it sometimes requires performing an investigation on the inner part of the reinforced earth wall. When deformation is observed due to the progression of corrosion in the reinforcing material, in addition, a chemical test is sometimes conducted, such as a pH test of backfilling material, chloride content, sulfide content, and electrical resistivity.

2) Pull-out test of Reinforcing Material

Pull-out test of reinforcing material is a major method to investigate the inner part of the reinforced earth wall. This investigation checks whether designed pull-out capacity is retained by a concerned wall, by directly pulling out a reinforcing material from the surface wall.

3) Investigation of Fundamental Ground

When the lack of bearing capacity of foundation ground is considered as a cause of wall deformation, it is preferable to examine the occurrence of deformation and to investigate foundation ground, etc.

5.10.12 Detailed Investigation of Culvert

(1) Basic Policy on Culvert Investigation

Detailed investigation on a culvert is performed when it is deemed necessary to check the soundness of the structure. Specific examples include a case when deformation is progressing when structural damage is concerned due to lack of bearing capacity, or when an inner section is becoming insufficient due to settlement.

The detailed investigation results shall be conducted to obtain the necessary material and data about the causes of deformation for appropriate countermeasure work. As a matter of course, obtained results shall be organized and documented to be efficiently used for the later operation work.

(2) Purpose and Item

Detailed investigation on reinforced concrete culvert is performed with the purpose of obtaining the material or maintenance/reinforcement countermeasures as well as identifying the form of deformation and the cause.

The major investigation items are the followings, which targets damaged parts and the inner wall section.

- ✓ Crack
- ✓ Stripping, exposed, and corroded reinforced bar
- ✓ Depression, settlement, abnormality on sealed joint

(3) Detailed Investigation Method

Investigation of the concrete bridge can be applied for detailed investigation method of damage on concrete culverts (e.g. crack, stripping, exposed and corroded reinforcing bar, etc.). When an abnormal structure profile is identified, the structural resistance of the culvert shall be checked as required.

Investigation of displacement is performed for phenomena of settlement, inner height, gap, displacement, and opening of sealed joint. In case a culvert structure is constructed on soft ground or a ground with significant changes of bearing capacity, it may lead to poor drainage, damage on joint, or breakage on the main body due to the depression of the culvert. In regard to investigation work, it is important to understand the current status by paying an attention to functional abnormalities.

1) Crack, stripping, exposed and corroded reinforcing bar, etc.

Methods of bridge investigation are applied to crack, stripping, exposed, and corroded reinforcing bar of the culvert.

2) Measurement of settlement and an inner height

It is recommended to place a fixed survey control point on a service road to understand the relationship of positions between the culvert and the service road. As for the measurement of the inner height of a culvert, a height from the road surface to ceiling slab shall be measured with staff and measure at the same position as settlement measurement.

3) Measurement on an uneven surface, displacement, gap opening on joint

This method measures the uneven surface of the ceiling slab, displacement of the side wall, gap opening of the joint, uneven road surface. If actual measurement positions are written on the surface of a culvert structure, it is possible to conduct a measurement again at the same position when the progression of deformation needs to be investigated.

5.11 Record and Report of Inspection Data

All data generated from inspections shall be properly referenced, compiled, validated, and presented in easily comprehensible forms A person in charge should keep in mind the following important points:

i) Inspection results should be recorded in certain uniform formats, directed in related publications.

ii) Compiled records shall be kept in an adequate manner so that they can be promptly referred when necessary, for example, at the time of major improvement projects, renovation projects, and disaster rehabilitation projects.

iii) Records should be continued to be kept throughout the operation and maintenance period.

iv) Even if there is no deformation nor damage identified, those results of "no deformation nor damage" should be recorded, since such information of "no deformation nor damage" is also an important result of the inspection.

Record and report of inspection data are critical in that road operator understands the condition of structures, develops future management plan, analyzes the progress of deformation/damage and their causes. In case severe damage or deformation is observed, which is classified into higher ranking, emergency countermeasures need to be conducted as much as possible. Concurrently inspectors need to report the condition to a person in charge. If close inspection cannot be performed due to difficulty of access to inspection target, for example, because of unavailability of inspection passage, they have to record the fact that inspection cannot be conducted due to difficult access. In addition, the record should be reported to a person in charge so that proper measures for inspection can be discussed and organized. These processes are indispensable to perform the efficient, accurate, and complete inspections without any omission.

The items to be recorded include inspector name, data of inspection, damage condition (including projected diagram), evaluation result, adopted countermeasures and their result, repair history, and the information whether inspection/monitoring is implemented or not.

5.11.1 Input to Data Management System

There are various types of highway maintenance management systems available today. Those systems in principle assist maintenance operators (1) to collect, store~~,~~ and analyze road information, (2) to support planning, implementing, and recording maintenance works, and (3) to manage to maintain major structures of the road such as pavement, bridges, long slopes, tunnels, etc.

A typical data management system consists of a road asset management system, material, and equipment management system, etc. The purpose of these systems is to manage road assets and basic data for road maintenance such as asset inventory, renewal history, reference data, etc.

A typical maintenance work assistant system consists of inspection data management system, roadwork restrictions management system, maintenance works system, etc. The purpose of this system is to efficiently plan and implement road maintenance works and to improve productivity and efficiency by comparing and analyzing the results periodically. Some of the representative management systems are presented below:

- Indian Bridge Management System (IBMS)

Indian Bridge Management System is being developed to serve as not only an inventory of all bridges and culverts on national highways but also a means of prioritizing bridge repairs based on the best life cycle cost. It stores inspection data in the form of objective and integrated evaluation. Then, it assesses the soundness of members of bridge structures and predicts the progress of the deterioration.

IBMS selects the optimal method of repair, renewal timing, and size, based on different scenarios comparing the budged constraint and total life cycle costs. It finally establishes a plan of repairs for all bridges. At this moment several states in India have adapted this system.

- Pavement Management System (PMS)

Pavement Management System (PMS) is a decision-making support system for efficient and preventive management of pavement. It encompasses a full project cycle - planning, design, construction, evaluation, and rehabilitation. It provides decision-makers with an optimum repair method derived from clearly established rational procedures.

The purpose of PMS is to make efficient pavement management and as a result to reduce the cost and the frequency of maintenance to offer good service to road users. PMS has the data of road information such as traffic volume, location, design, and repair history, and pavement surface property data. By considering these data comprehensively, PMS tells us the most efficient way to repair damaged pavement including kinds of repairs, sections to be repaired, and method to be used, and priority of sections.

- Highway Development and Management System (HDM-4)

Highway Development and Management System (HDM-4) is computer software for Highway Development and Maintenance Management System, developed by the World Bank. It is a decision-making tool for checking the engineering and economic viability of investments in road projects. HDM-4 is the new windows version after HDM-III with the incorporation of various new features so that it can be used in any locality of the world with any environmental and engineering situation. There are four main areas of application: (1) Strategic Planning, (2) Roadwork Programming, (3) Project Analysis, and (4) Research and Policy Studies.

- Emergency Report Support System (ERSS)

Emergency Report Support System (ERSS) utilizes commercial mobile phones with the function of a camera and GPS. The mobile phone is preinstalled with a software program to be connected to the ERSS central server. A person on the spot of an inspection/accident can send relevant information about the location, description, and pictures to the ERSS central server using mobile communication. All the people concerned with the inspection/accident can access the ERSS central server to retrieve the information to grasp the current situation and to take any necessary actions

There are three primary objects of the system, which are (1) To assist in reporting on real-time field conditions, (2) To support sharing information among people concerned, and (3) To produce a quick report in an emergency situation on road defects, car accidents, natural disasters, etc. The system is capable of searching past events, locating the GPS mobile phones, and outputting data in excel format.

CHAPTER 6 MAINTENANCE PLANNING ANDWORKS

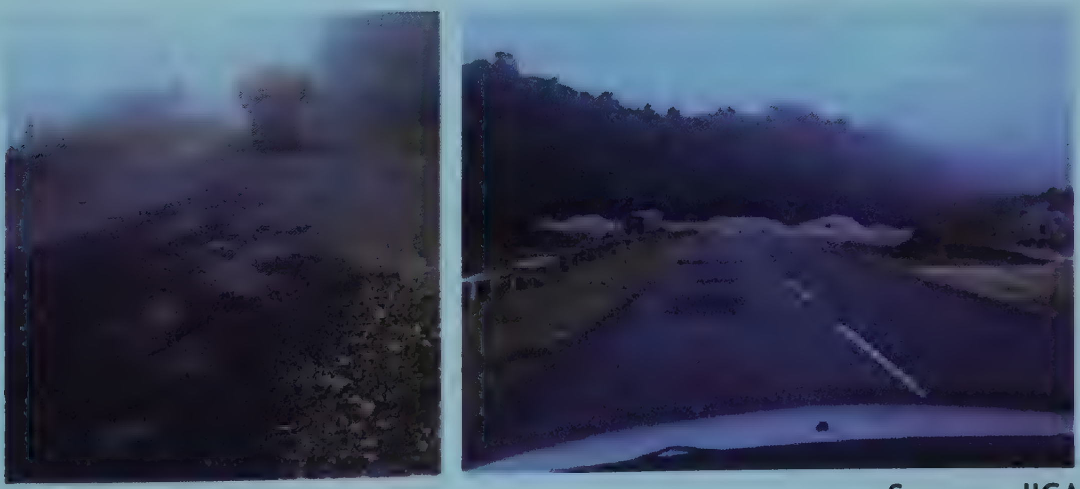
6.1 Introduction

Highways in mountainous regions play an indispensable role for the regions where the highways pass through, and the importance of maintenance is getting higher and higher with the growth of surrounding regions. It is the responsibility of road administrators that shall conduct adequate maintenance in a timely manner by regular inspection and investigation in order to maintain the roads anytime in good condition.

In principle, maintenance work needs some form of traffic regulation in most cases. On major corridors with heavy traffic, congestion may happen, leading to the decrease of service level for road users. In this regard, planning of maintenance work shall be meticulously conducted including the consideration of timing and method of the work, taking into account of characteristics of traffic and the role of the concerned sections.

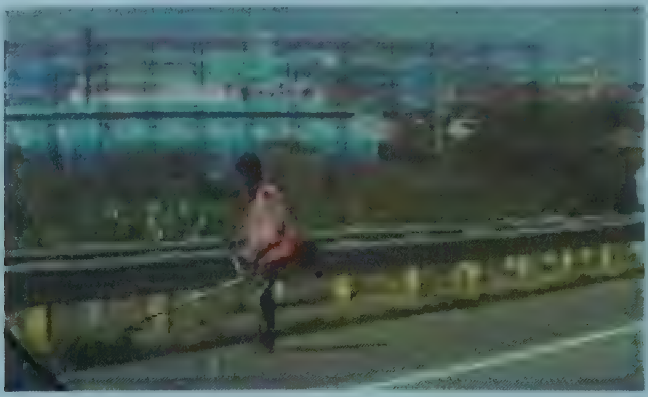
Moreover, officials in charge shall pay due attention to the guarantee of safety during the course of maintenance work, and needless to say, it is for everyone related to the worksite, not only for the road users but also workers at the site and officials in charge.

This guideline aims to work as a basis of maintenance planning and maintenance work. It covers road cleaning, planting, and maintenance repair work in each chapter.



Source: JICA Expert team

Figure 6-1: Degradation of Pavement and Repair work on NH40 in Meghalaya



Source: JICA Expert team

Figure 6-2: Weed Cutting on Mumbai-Pune Expressway in Maharashtra

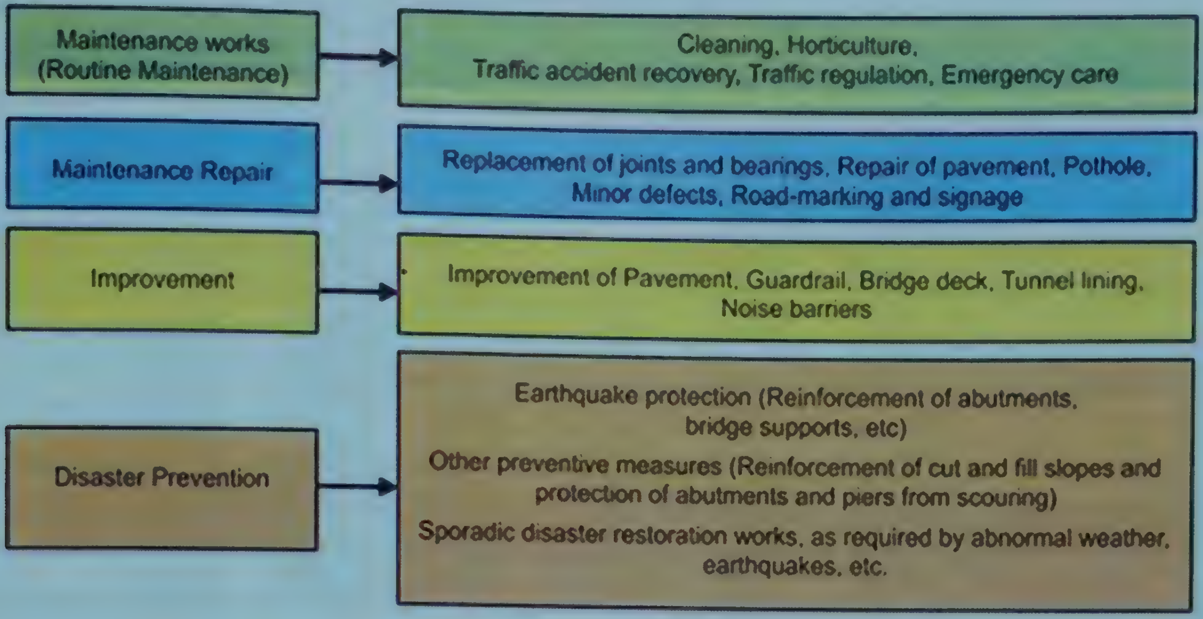
6.1.1 Types of Maintenance Work

Maintenance of hill roads includes various tasks such as maintenance of embankment, slopes, bridges, tunnels, and other structures; cleaning and inspection for ensuring the safety of road users; maintenance of information system for providing traffic information on a continuous basis.

Maintenance engineers are required to keep roadways always in good condition, at the same time improve the efficiency of the maintenance system. Generally speaking, maintenance work is broadly classified as:

- Maintenance Works (Routine Maintenance): This covers inspection, renovation, cleaning of road and associated facilities including recovery of traffic accidents, etc.
- Maintenance Repair: This covers pavement repair (all types of distresses), bridge surfacing renovation, and painting of metallic and concrete surfaces to maintain the traffic requirements.
- Improvement: This covers improvement (i.e. up-grading) of function, serviceability as well as structural efficiency of the pavement, structures, and environment
- Disaster prevention: This covers the emergency measures/works to mitigate the adverse effects of earthquakes, storms, and floods along with man-made casualties.

Tasks in association with each type of maintenance work are presented in Figure 6-3.


Maintenance works (Routine Maintenance)
Cleaning, Horticulture, Traffic accident recovery, Traffic regulation, Emergency care
Maintenance Repair
Replacement of joints and bearings, Repair of pavement, Pothole, Minor defects, Road-marking and signage
Improvement
Improvement of Pavement, Guardrail, Bridge deck, Tunnel lining, Noise barriers
Disaster Prevention
Earthquake protection (Reinforcement of abutments, bridge supports, etc)
Other preventive measures (Reinforcement of cut and fill slopes and protection of abutments and piers from scouring)
Sporadic disaster restoration works, as required by abnormal weather, earthquakes, etc.

Source: JICA Expert team

Figure 6-3: Types of Maintenance Work

6.1.2 Preventive Maintenance and Reactive Maintenance

Maintenance of hill roads needs a planned strategy of cost-effective and time-saving treatments. A preventive approach rather than breakdown shall be adopted for this purpose, retards future deterioration, and maintain or improve the functional conditions.

Preventative maintenance takes a proactive approach in reducing time-consuming rehabilitation and reconstruction and the associated traffic disruptions. Repairs made for damage in the early stage of deterioration will be on a small scale and be simple, consequently, minimizing the total cost of life-cycle maintenance cost (LCC). Life spans will also become longer. Maintenance works that are planned on a regular basis can be carried out by regular maintenance staff. This helps to equalize the maintenance workforce and cost over the years of a maintenance period.

Inspection is the key element in preventive maintenance that determines all triggers to necessary maintenance activities. By detecting an early stage of deterioration, and checking the development pattern of deterioration, it is possible to find an optimal threshold level to restraint the deterioration. The key is to apply the right treatment at the right place at the right timing.

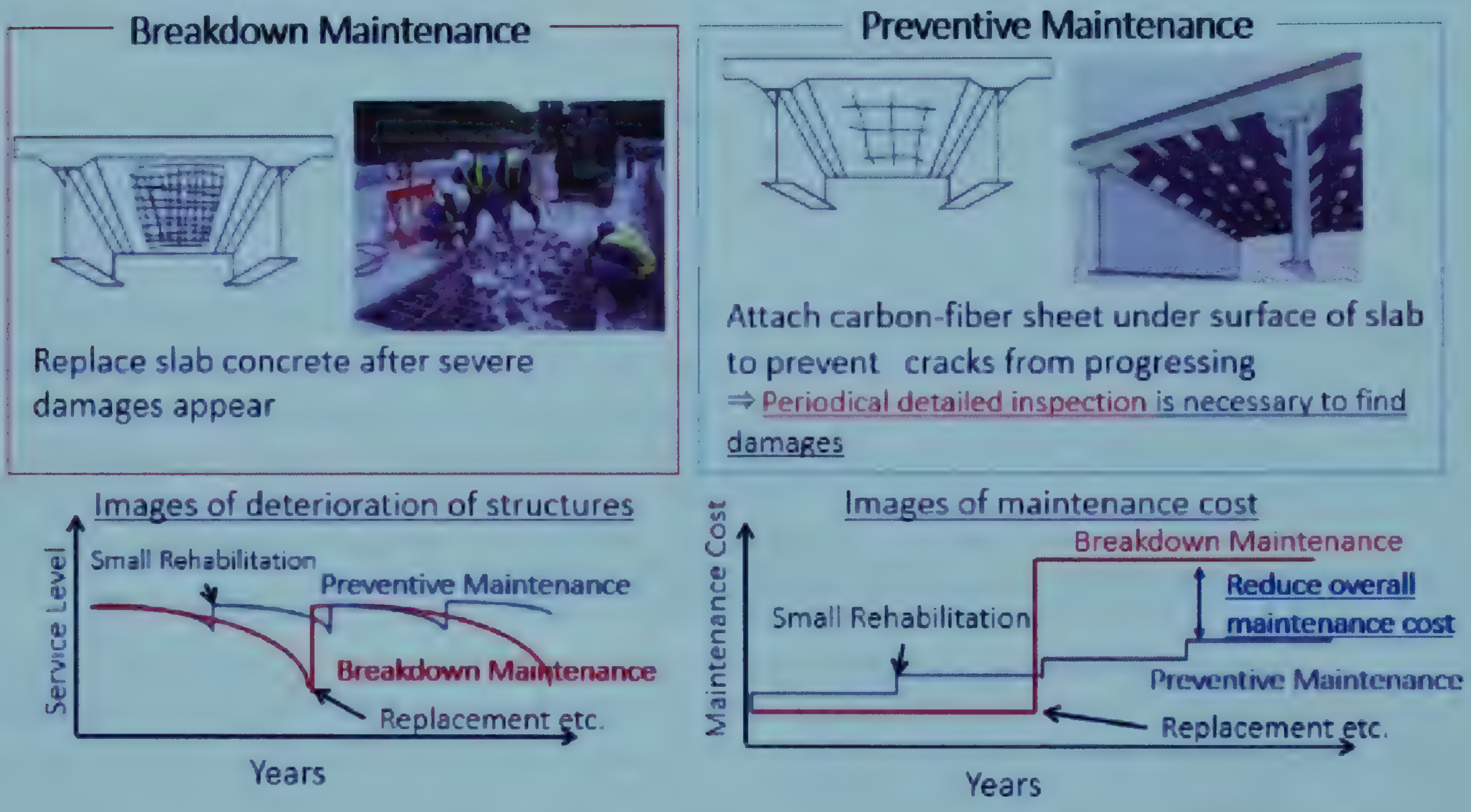
The benefits associated with preventive maintenance are as follows:

(i) Pre-planned maintenance
    a) Maintenance time is known
    b) Optimal usage of the workforce, machine, spare parts, and equipment
(ii) Optimal maintenance level (most cost-effective treatment)
    a) Best timing and type to treat the deterioration
    b) Planning of grouping maintenance, which will minimize disturbance to traffic.
(iii) Service level of road condition is relatively high all time period.

Actual practices of preventive maintenance in the maintenance field are to carry out remedial treatment before the defect reaches "AA". To plan a repair for "AA" defects is interpreted as "breakdown maintenance".

Crack filling in the pavement is the most important and cost-effective preventive maintenance. It prevents rainwater from penetrating into pavement structure and prolongs the life of the pavement. In the same manner, finding minor defects in bridge structures and planning repairs before the defects develops into severe functional deterioration is also effective preventive maintenance.

Figure 6-4 shows an outline of preventive maintenance. The Red line shows breakdown maintenance and the blue line shows preventative maintenance. Especially, the left bottom figure shows the comparison of the service level. The service level of preventative maintenance is high most of the time. As per maintenance cost, the preventative maintenance is rather small compared with the breakdown maintenance (left bottom figure).

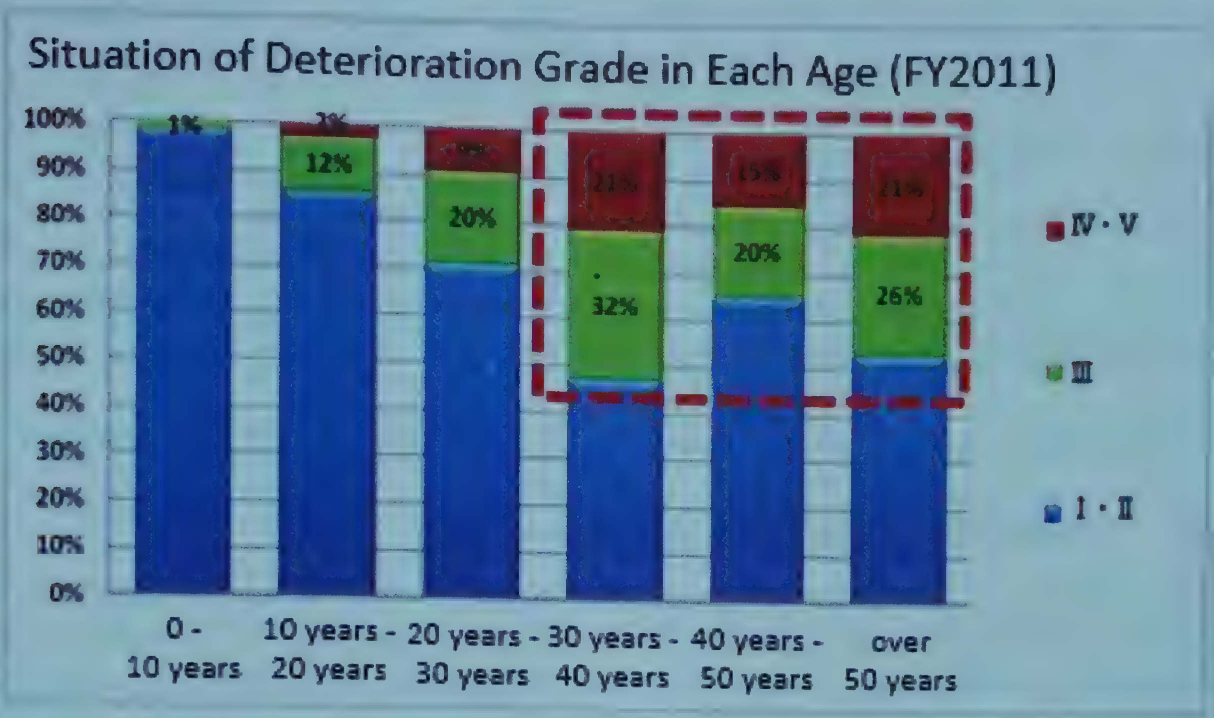

Breakdown Maintenance
Replace slab concrete after severe damages appear
Preventive Maintenance
Attach carbon-fiber sheet under surface of slab to prevent cracks from progressing
⇒ Periodical detailed inspection is necessary to find damages
Images of deterioration of structures
Service Level
Small Rehabilitation
Preventive Maintenance
Breakdown Maintenance
Replacement etc.
Years
Images of maintenance cost
Maintenance Cost
Breakdown Maintenance
Small Rehabilitation
Reduce overall maintenance cost
Preventive Maintenance
Replacement etc.
Years

Source: JICA Expert team

Figure 6-4: Outline of Preventive Maintenance

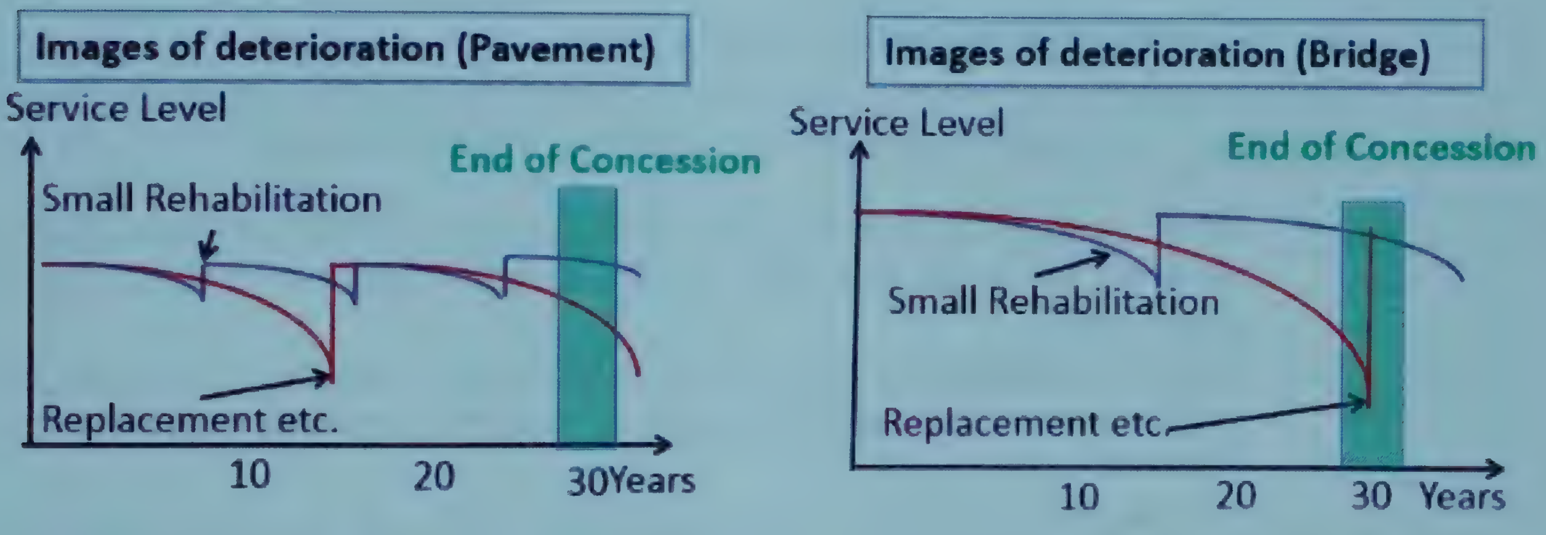
Figure 6-5 shows experience in Japan and describes bridge deterioration by years. After 30 years from construction, severe deterioration (i.e. grade Ⅳ & Ⅴ) is rapidly increasing. In the case of PPP projects in India, the replacement cost of structures would be one of the argument points between owners and concessionaires. By the introduction of the preventative maintenance philosophy, an owner can receive road assets in a better condition at the end of the concession. At the same time, concessionaires and an owner can avoid time-consuming and costly arguments on a topic about who will be in charge of performing major maintenance at the end of the concession (See Figure 6-6).

For the implementation of preventative maintenance, a detailed inspection is essential. CHAPTER 5 describes inspection in detail.



Source: JICA Expert team

Figure 6-5: Bridge Deterioration by Service Years


Images of deterioration (Pavement)
Service Level
End of Concession
Small Rehabilitation
Replacement etc.
10
20
30Years
Images of deterioration (Bridge)
Service Level
End of Concession
Small Rehabilitation
Replacement etc.
10
20
30 Years

Source: JICA Expert team

Figure 6-6: Maintenance Cycle and Concession Period

6.2 Cleaning Works

The central purpose of cleaning work is to maintain the function of the roadway and to preserve the environment and beauty on the roadway and along roadsides. Dirt and dust on road surface lead to disturbance of traffic. Dirty of traffic safety facility results in not only the cause of corrosion but also degradation in structure strength and optical guidance effect. Deposit of dirt or sand in drainage facility inhibits the function, leading to not only ponding on the road surface but also critical damage to road structure and roadside facility. Thus, removal of dirt and dust on the road surface or related facility aims to realize safe, reliable, and comfortable highways, which prevents traffic disturbance, disaster, and road accident due to dust and dirt before it happens.

In the context of mountainous highways, a road administrator shall perform adequate cleaning, especially drainage cleaning, based on sound planning of cleaning works, since hill roads pass through various regions in different characteristics. Depending on traffic, roadside condition, climate, etc., the condition of dirt, dust, fallen leaves, and fallen materials differs. Taking account of this point, this chapter highlights the fundamental approach and method of cleaning and detail of drainage cleaning.

6.2.1 Planning of Cleaning Work

Methods and efficiency of cleaning works depend on each condition of a concerned section and roadsides. Thus, a road administrator should fully understand the targeted section, and then study targeted structures of cleaning, timing, duration, frequency, and so forth so that they can perform efficient and safe cleaning work.

In particular, a road administrator shall keep the following points in mind:

(i) A clear understanding of the condition

The degree of dirty on the road surface and road facility depends on traffic volume, heavy traffic volume, geometric structure, topographic condition, weather condition, roadside environment. Therefore, it is necessary to understand the condition of dirt and dust based on the result of regular patrol and inspection. Especially, cleaning of drainage system before every rainy season or approach of a tropical cyclone is critical so that it does not trigger ponding on road surface nor slope failure.

(ii) Consideration of cleaning works

Road administrators shall ensure that workers involved in cleaning tasks shall pay attention to the following points during the course of their works:

- When conducting cleaning work near passing vehicles or pedestrians, carefully perform works so that dust or dirt is not scattered towards the vehicles or pedestrians.
- When conducting cleaning work near houses, buildings, or agricultural fields (especially harvest season), carefully perform works so that dust or dirt is not scattered.
- In case of bad weather with high wind, dirt and dust is scattered, and work efficiency decreases
- During the season of leaf fall, the drainage facility is more likely to be clogged by fallen leaves.
- On mountainous highways in a snowy cold region, more dirt and dust are produced in snowmelt season.

(iii) Frequency of cleaning work

For the determination of the frequency of road cleaning, it is important to formulate an adequate cleaning plan by considering various elements, such as traffic volume, heavy traffic volume, characteristics of the concerned section (e.g. industry road or scenic road).

(iv) Safety

Most cleaning works need traffic regulation, because of the nature of the works, such as by a slow-moving vehicle or walking workers conducting sweeping or removing dust and dirt on foot. Thus, a road administrator shall give the highest priority to safety. Cleaning works are conducted repeatedly, and therefore, guarantee safety before the work by vehicle inspection and health checkup for workers.

6.2.2 Classification of Cleaning Work

Cleaning works are designed to relieve roads of litter, soil, dust, etc. to allow them to perform normal functions, preserve road and roadside environmental amenities, and maintain the ideal landscape, as classified below:

Table 6-1: Classification of Cleaning Work

Classification	Sub-classification	Working method		Coverage
Surface cleaning	Type A cleaning	Cleaning by sweeper		Main line and ramp way shoulders and their peripheries
	Type B cleaning	Washing by sprinkler truck		Main line and ramp way shoulders beyond reach of sweeper
	Type C cleaning	Manual cleaning to supplement type A or B cleaning		Mostly, road surfaces
	Type D cleaning	Manual cleaning of roads not covered by type-A or B cleaning		Road surfaces
Cleaning of road attachments, etc.	Crash barriers	A	Manual cleaning	Guardrails
		B	Manual cleaning	Handrails
	Traffic signs	A	Manual cleaning	Delineators, distance markers, emergency telephone signs
		B	Manual cleaning	Overhead traffic signs
		C	Manual cleaning	Signs on the shoulder
		D	Manual cleaning	Traffic control, warning, and other signs installed on the shoulder
	Drain pipes	A	Mechanical cleaning	Underground drain pipes (150-300 mm dia)
		B	Mechanical cleaning	Underground drain pipes (350-1200 mm dia)
		C	Mechanical cleaning	Circular waterways
	Gutters	A	Manual cleaning	Rolled gutters
		B	Manual cleaning	Uncovered gutters
		C	Manual cleaning	Covered gutters
	Median strips (inlets)		Manual cleaning	Median strip (inlets)
	Catch basins	A	Manual cleaning	Catch basins
		B	Mechanical cleaning	Catch basins
	Joints	A	Mechanical cleaning	Joints on the two-lane (each way) highway
		B	Mechanical cleaning	Joints on the three-lane (each way) highway
	Catch basins on bridges and viaducts or highway bridges	A	Manual or mechanical cleaning	Catch basins on bridges and viaducts
		B	Mechanical cleaning	Cleaning of catch basins and drain pipes of bridges and viaducts to assure smooth flow
	Tunnel side walls	A	Mechanical cleaning	Cleaning of tunnel side walls (interior boards, etc.) with tunnel washer and sprinkler truck
		B	Mechanical cleaning	Cleaning of tunnels side walls (interior boards, etc) with multi-purpose wet cleaner and sprinkler trucks
		C	Mechanical cleaning	Cleaning of tunnels side walls (interior boards, etc) with a multi-purpose dry washer
Rest area and interchange cleaning	Type A cleaning	Manual cleaning		Service and parking areas at wayside amenities (road areas)
	Type B cleaning	Manual cleaning		Service and parking areas at wayside amenities (garden areas)
	Type C cleaning	Manual cleaning		Interchanges (garden areas)
Associated facilities cleaning	Washrooms	Manual cleaning		Washrooms in wayside amenities and bus stops (windows, floors, washrooms, stools, and bowls, etc.)

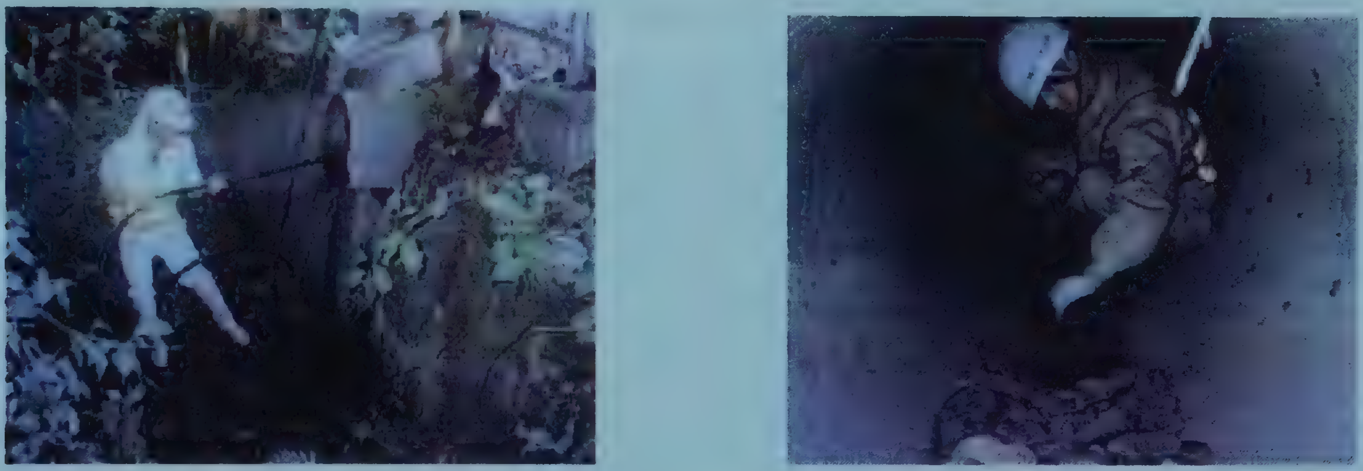
[18]

6.2.3 Details of Cleaning Work

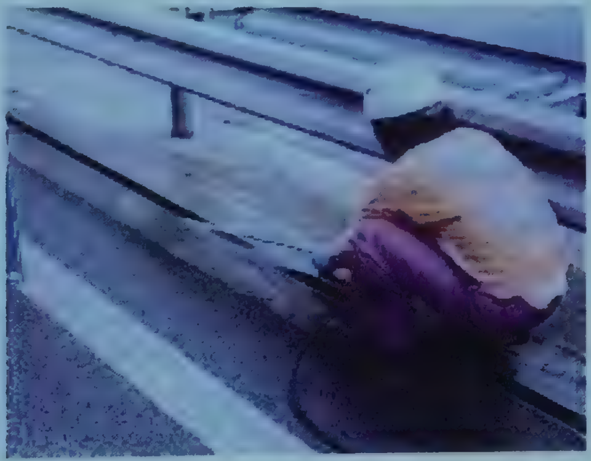
This guideline highlights cleaning works of the drainage system, bridge, and tunnel in consideration of its importance in the context of hill roads. Readers should refer to relevant guidelines for the detail of the remaining items.

(1) Cleaning of Drain Pipe

This involves the removal of soil, sand, and dust deposits from underground drain pipes, gutters, and round-shaped drains. In this operation, high-pressure washers or sprinkler trucks are used to flush deposits to catch basins by means of powerful hydraulic pressure. Where soil, sand, etc. is coagulated beyond the capacity of hydraulic pressure, workers take part in manual cleaning. Before rainy and typhoon seasons come, thorough patrol inspection and cleaning is essential



a) Type B Cleaning by High-Pressure Water b) Type B Manual Cleaning



c) Type C Cleaning of Circular Type Drain

[15]

Figure 6-7: Cleaning of Drain Pipe

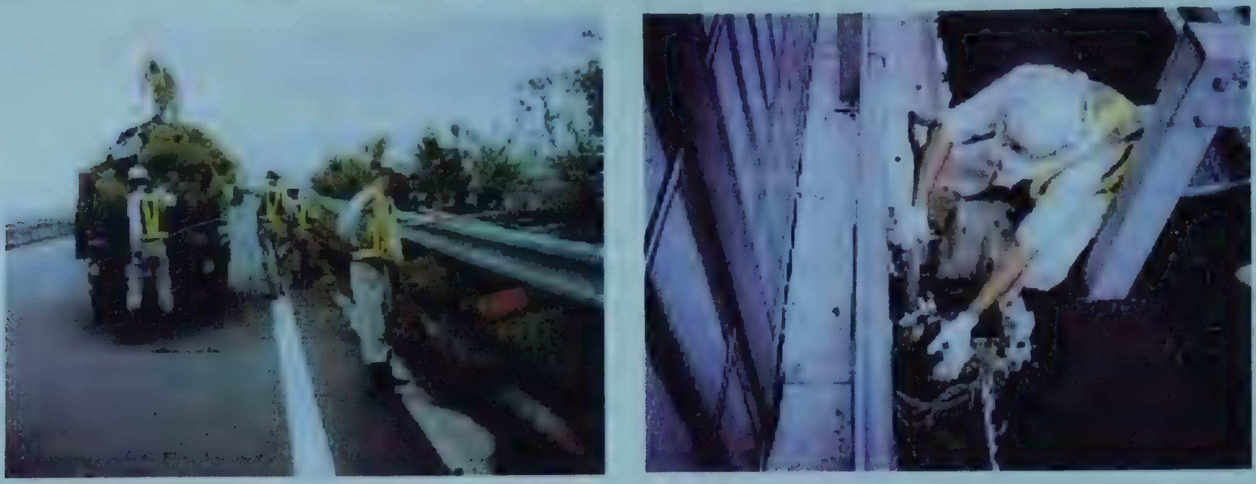
(2) Cleaning of Gutter

This involves manual removal of soil, sand, and trash deposits from U-drains and rolled gutters installed on the shoulders, median strips, longitudinal drains on the slope, slope toes, and berms. Branches of trees and grass over drains and gutters should be cut off or pruned. Soil, sand, etc. should be carried to designated or remote dumps to ensure they do not flow back into these drains or gutters.

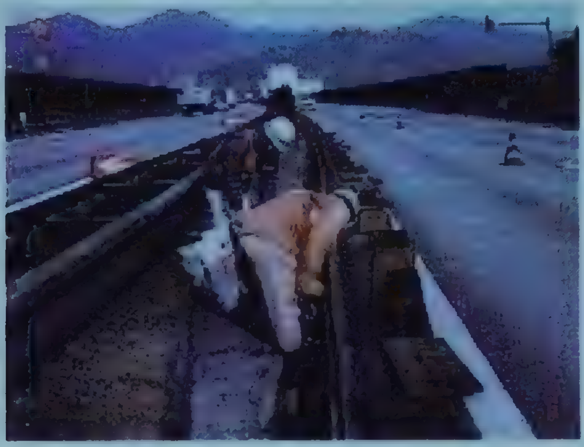
As mentioned in the above section, thorough patrol inspection and cleaning are essential before rainy and typhoon seasons come. There are three categories of cleaning of gutters as follows:

- Type A cleaning (gutters): Manual cleaning of rolled gutters

- Type B cleaning (gutters): Manual cleaning of uncovered gutters
- Type C cleaning (gutters): Manual cleaning of covered gutters



a) Type A Cleaning (Gutters)   b) Type B Cleaning (Gutters)



c) Type C Cleaning (Gutters)

[15]

Figure 6-8: Cleaning of Gutters

(3) Cleaning of Median Strip Inlet

This involves manual removal of soil, sand, and dust deposits accumulated at rainwater drainage inlets installed on the median strip. Thorough patrol inspection and cleaning are essential before rainy and typhoon seasons come. Also, it is preferable that gutters should be cleaned to remove soil and sand deposits concurrently with the related cleaning mentioned in the above sections.

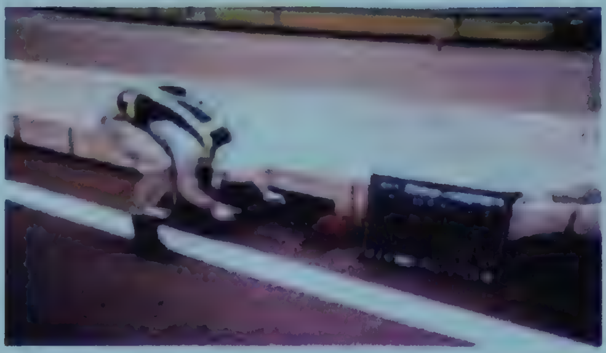


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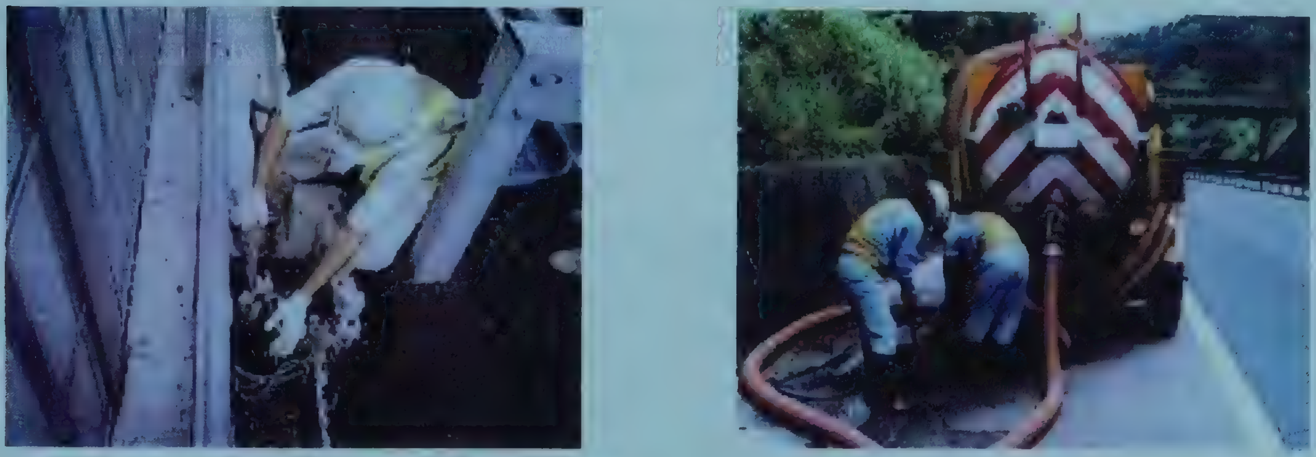
Figure 6-9: Cleaning of Median Strip Inlet

(4) Cleaning of Catch Basin

This involves the removal of soil, sand, and dust deposits from catch basins either manually or mechanically using a vacuum sweeper attached with a mud sucker. Thorough patrol inspection and cleaning before rainy and typhoon seasons come is essential. Also, the catch basin should be tightly covered after cleaning to avoid the hazard of accidents. Where soil and sand deposits are coagulated, it is adequate to soften them by hand to ease mud suction. There are two types of cleaning of catch basin as follows:

- Type A cleaning: Manual cleaning of catch basin
- Type B cleaning: Mechanical cleaning of catch basin



a) Type A Cleaning (Catch Basin) b) Type B Cleaning (Catch Basin)

[15]

Figure 6-10: Cleaning of Catch Basin

(5) Cleaning of Bridge Joint

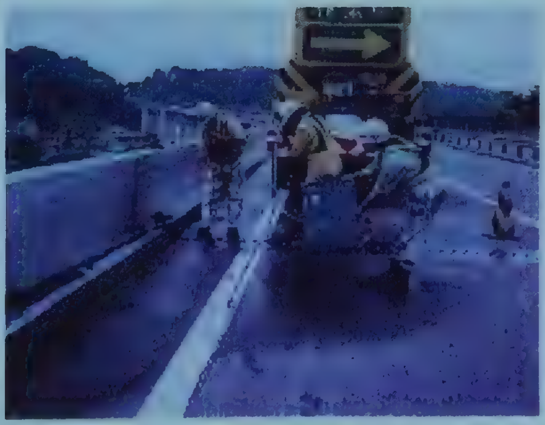
This involves manual or mechanical (using high-pressure washer) removal of soil, sand and dust deposits in the drainage system and pipes of steel comb-type expansion joints installed on bridges and viaducts. It is important to keep joints always well maintained in order to prevent corrosion or damage as well as enable them to retain good drainage performance.

For the actual work at the site, the following two points should be kept in mind:

- Start cleaning at the higher end of a slope
- Clean joints carefully so as not to splash over pedestrians and vehicles passing under the bridge with mud.

There are two categories of cleaning of bridge joints as follows:

- Type A cleaning: Cleaning of joints on a highway with two lanes in each direction
- Type B cleaning: Cleaning of joints on a highway with three lanes in each direction



[15]

Figure 6-11: Cleaning of Bridge Joint (Type A Cleaning)

(6) Cleaning of Catch Basin on Bridge

This involves manual or mechanical (with high-pressure washer truck) removal of soil, sand, and dust deposits in catch basins and drain pipes of bridges and viaducts. Thorough patrol inspection and cleaning before rainy and typhoon seasons come are essential. Also, the basin should be tightly covered after cleaning to avoid accidents. There are two categories of cleaning of the catch basin, as follows:

- Type A cleaning: This involves manual or mechanical (with high-pressure washer truck) cleaning of bridges and viaducts.
- Type B cleaning: This involves manual cleaning of catch basins and drain pipes of bridges and viaducts with a high-pressure washer truck.

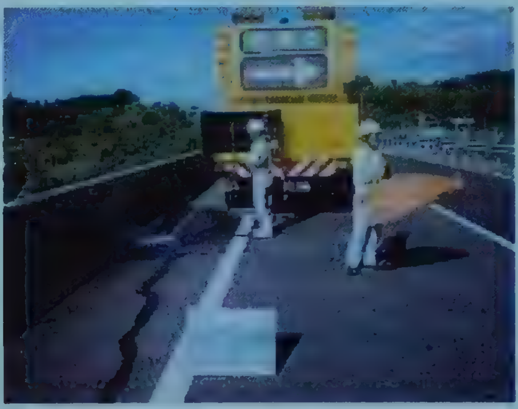


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Figure 6-12: Cleaning of Catch Basin on Bridge

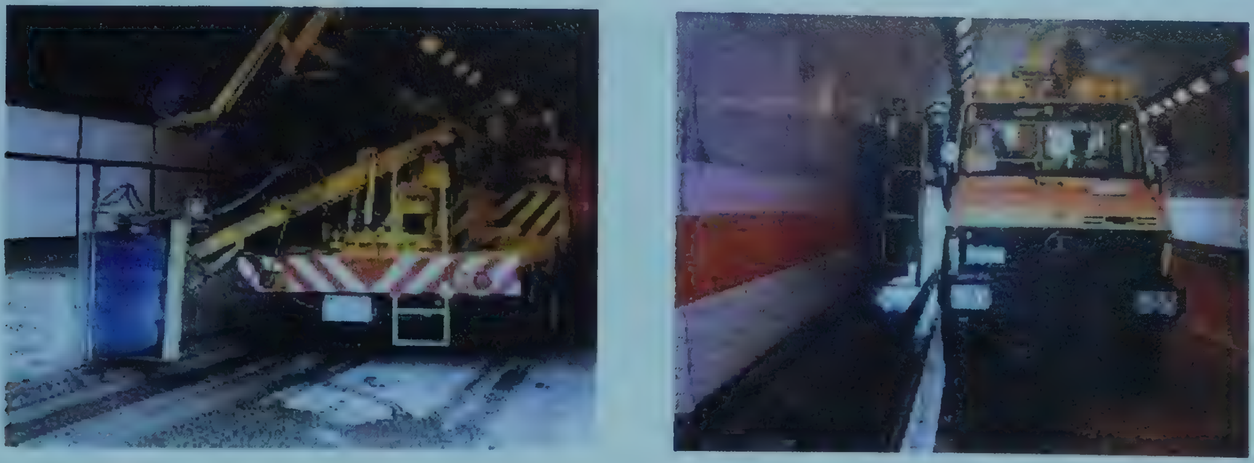
(7) Cleaning of Tunnel Side-wall

This involves manual and mechanical (with washer truck) cleaning of tunnel side-walls in dry or wet modes, using a sprinkler truck for washing. To conduct the work, it is necessary to pay attention to the following points:

- Take safety precautions for passing vehicles, since a cloud of dust is raised during the dry cleaning,
- The drain system should be prechecked to inhibit the outflow of foul cleaning water.
- Adjust the cleaning brush to the desired contact pressure to prevent damage to interior boards in the tunnel.
- Pay attention to tunnel facilities such as CCTV, delineators, etc.
- Use manual cleaning to compensate for unevenness produced by mechanical cleaning.
- Preferably, clean inspection galleries, handrails, etc. at the same time.

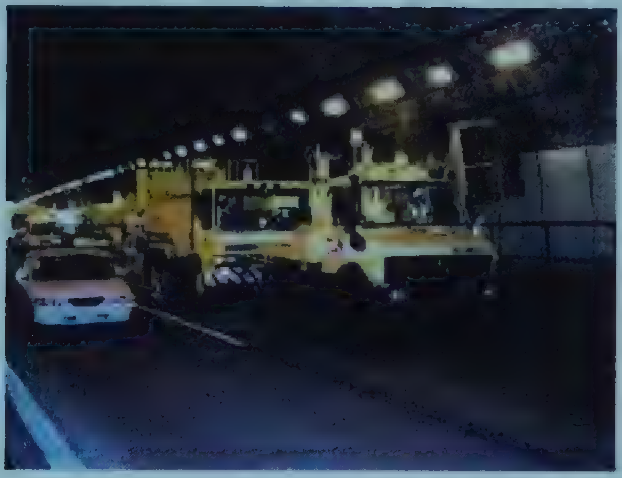
There are three types of cleaning of tunnel side-walls as follows:

- Type A cleaning: This involves washing tunnel side walls (interior boards, etc.) with a sprinkler truck after cleaning by a washer truck.
- Type B cleaning: This involves washing tunnel side walls (interior boards, etc.) with a sprinkler truck after cleaning by a multi-purpose washer truck.
- Type C cleaning: This involves mechanical cleaning of tunnel walls (interior boards, etc.) by a multi-purpose dry cleaning truck.



a) Type A Cleaning (Tunnel)

b) Type B Cleaning (Tunnel)



c) Type C Cleaning (Tunnel)

[15]

Figure 6-13: Cleaning of Tunnel Side-Wall

6.3 Planting Work

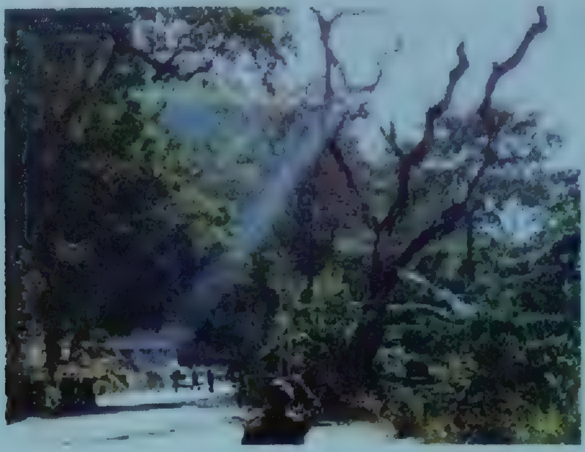
6.3.1 Purpose of Cleaning Work

The planting works generally aim to fulfill the roles of planting for roadways, as follows:

i) To preserve environment
ii) To adjust, enhance, and improve the scenic view
iii) To improve road safety in terms of traffic safety and prevention of disaster

It is important to understand that the abovementioned roles of planting do not rely on a single or individual tree but on the comprehensive group of trees and plants. Planting works provide the road users with a sense of green nature.

Just after planting work, a form of trees tends incomplete, even grownup trees, and it is after a certain period of day-to-day maintenance that the planted trees fulfill their intended function. In this regard, it is essential to conduct various maintenance works which contribute to the healthy development of plants as well as maintaining of intended function.



Source: JICA Expert Team

Figure 6-14: Tree Cutting on NH10 in the State of West Bengal

6.3.2 A mindset of Planting Work

To keep mountainous highways in a good condition is critical for the highways to serve their intended roles. In this sense, road administrators should pay due attention to planting work along with cleaning work and repair work. However, the more detail and the greater intensity of works they perform, the more budget and workload it will be necessary. Thus, it is essential to take account of the aspects of Life Cycle Cost (LCC), the satisfaction of road users, and cost-benefit performance (B/C). Simultaneously, planning of plantation work on a yearly and mid-term basis and review of inspection results by planting professionals are other points to be considered.

6.3.3 Planning of Planting Work

For the planning of planting work, it is vital to understand the purpose and function of targeted plantings, growing condition, size of trees, the effect of planting work, traffic volume, characteristics of a targeted section, and surrounding environment. Moreover, road administrators should not repeat the same work every year but put a certain effort to find out the more efficient and safer method of planting work, considering of location of the base office, capacity of machines, disposal of scraps, and cut trees and weed. In particular, the road administrator should review and understand the following points from (i) to (v) for the planning and then have a meeting with the planting expert, if available.

(i) Plan of landscape and current condition

- Landscape basic design

Plan of landscape basic design specifies a framework of greening and philosophy of planting. This document plays a key role to formulate middle and long-term maintenance planning.

- Landscape detailed design

Based on the types of plantings and their composition specified by landscape basic design, landscape detailed design determines the size of materials, their amount, and points to consider for the subsequent phase of construction. To understand the underlying concept of design, understanding ~~of~~ this material is meaningful.

- As-built document at the end of the construction phase

It is often the case that there are some differences existing between the document of detailed design and the condition on-site, since the construction of planting is conducted flexibly, upon the good understanding of the concept of detailed design. In this regard, the exact number and type of trees can be checked by this document

- Drawing of planting for maintenance

In Japan, drawings of planting are created and maintained by road administrators for effective and efficient maintenance. It has data on types, height, areas of trees in an organized manner. Also, the database of the drawing can retain the data of location, length, width, and area of targeted slopes, as well as the regular frequency of planting work, the workload each year.

- Results of periodical planting inspection

Inspection results of planting typically contain the data on the growing condition of planting, damage by harmful insects, locations which need immediate countermeasures and affect on surrounding areas. This information is valuable in that it can realize yearly planning of efficient and economical planting work.

- Investigation results

The investigation is conducted to tackle unexpected problems by experts in an intensive manner or to monitor the changing condition of green areas. These materials can be reflected when the development of mid-term or long-term planning of planting work.

(ii) Timing and method of planting

The growing Condition of planting differs according to traffic volume, heavy traffic volume, geometric design of mountainous highways, topography, climate, and surrounding condition. For the planning of planting, it is necessary to fully understand not only these characteristics but also the botanical characteristics of targeted plants. Also, more attention is necessary when the targeted plants are in the vicinity of houses or agricultural farms. Moreover, harsh weather in the middle of summer or winter can have a negative effect on plant physiology and thus may lead to the adverse effect on the targeted plants and surrounding area. Therefore, planting works in such a season should be avoided as much as possible.

(iii) Frequency of planting work

For the determination of the adequate frequency of planting works, various features such as inspection results, traffic volume, heavy vehicle traffic, characteristics of targeted section (industrial corridor or scenic routes, etc.), existence of wayside amenities, etc. should be taken into account.

(iv) Safety

Some planting work needs traffic regulation and uses slow-moving vehicles. Thus, it is crucial to ensure the safety of road users, workers, and officials in charge. Typically, planting works have a nature of repetition over several days. Also, chemicals and machines are often used for work. In this regard, it is necessary to avoid negligence due to repeated work as well as to follow the specified method of usage in case of using chemicals and machines.

6.3.4 Classification of Planting Work

Planting work can be classified into five categories based on the targeted plants, as in Table 6-2.

Table 6-2: Classification of Planting Work

Category	Contents of Work	Working method
Trees	Care of independently planted trees and shrubs and maintenance of hedges and row-planted trees	(1) Pruning (2) Manuring (3) Insecticide spray (4) Weeding (5) Weed-vine clearing (6) Irrigation (7) Other maintenance (renovation of tree props, protection of trees from snow and wind, mulching, nursing of injured, sickly, fallen or decayed trees)
Forests	Nursing of existing forests and saplings to form new forests in the future	(1) Weeding cutting (2) Supplementary planting (3) Root treading (4) Fertilization (5) Raising up fallen trees, (6) Thinning, (7) Weed-vine clearing, (8) Insecticide spray, (9) High branch cutting (10) Branch cutting
Nursing of turfs	Turfs in the median strips, in the loops interchanges and service/parking areas and lawns around buildings	(1) Herbicide spray (2) Manual weeding (3) Lawn mowing (4) Insecticide spray-on turfs (5) Lawn fertilization (6) Topdressing (7)Aeration
Nursing of planted slope	This involves nursing of plants on cut or embankment slopes close to the ramps of the main lines, interchanges, and wayside amenities/parking areas, and maintenance of verge shoulders.	(1) Slope fertilization (2) Herbicide spray on the slope (3) Grass cutting (4) Removal of rough weed (5) Protection of plants from harmful insects (6) Felling shrubs (7) High branch cutting (8) Thinning
Gardening fixtures	Maintenance of promenades, benches, outdoor tables, pergola, water fountains, etc.	(1)Repair (2)Repainting (3)Replacement

[18]

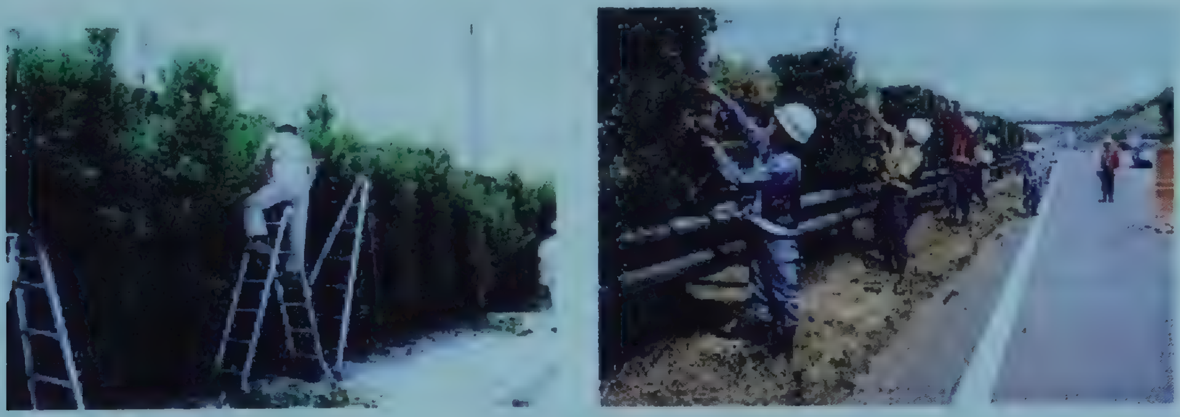
6.3.5 Detail of Planting Work

(1) Pruning

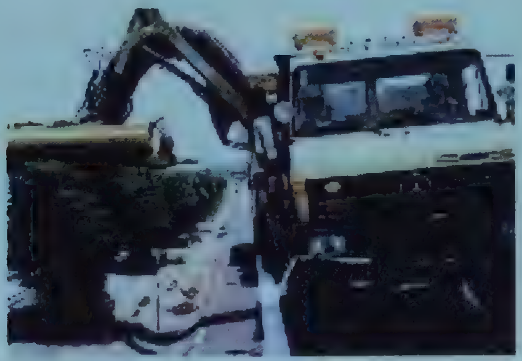
This is the manual or mechanical cutting off of limbs and twigs of trees for better shape. Pruning time varies with the species of trees planted. Commonly, autumn (October through November) is the best season for pruning coniferous trees. For evergreen trees, the ideal season for pruning is late spring to early summer (May through June) when new buds halt growth after sprouting, and early autumn (September through October) when summer shoots and long shoots stop growing up after second growth. For deciduous trees, July through August (the pre-typhoon season) when fresh green leaves have matured into solid leaves, and November through March when leaves fall off the trees, are the optimum season for pruning. The months mentioned in the parentheses are the case of Japan and should be flexibly changed according to the concerned area and region.

There are largely three types of pruning works:

i) Pruning (manual): Manual trimming, cutting off, and thinning of limbs and twigs of trees
ii) Pruning (mechanical): Mechanical trimming, cutting off and thinning of limbs and twigs of trees by such as hand-held trimmer
iii) Pruning (with the multi-purpose vehicle): This involves pruning with a special vehicle attached to the trimmer.



(a) Manual (b) Mechanical



(c) Multi-Purpose Vehicle

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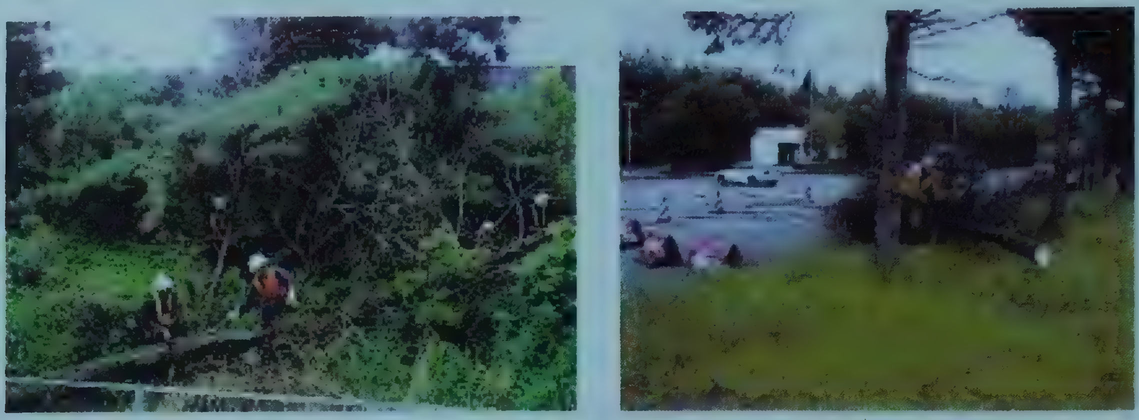
Figure 6-15: Pruning Work

(2) Removal of Decayed or Damaged Tree

Decayed or damaged trees not only spoil a scenic view but may also result in spreading trees infested with harmful insects. Left unattended, they could fall off by themselves spontaneously. Potentially, they can threaten the health of local people and damage nearby facilities, too. For this reason, they should be immediately uprooted and moved away.



(a) On Embankment Slope (b) At Wayside Amenity

[15]

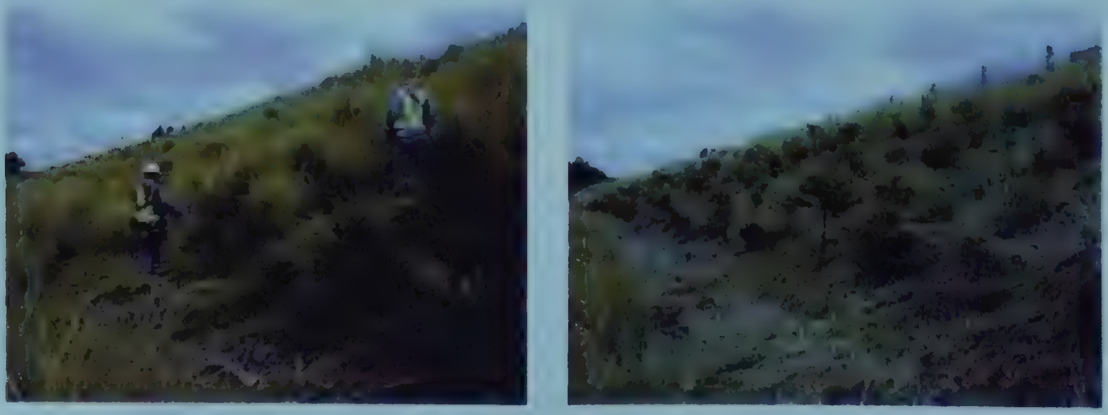
Figure 6-16: Removal of Decayed or Damaged Trees

(3) Weed Cutting

This involves manual cutting of weeds which grow thick around young trees, preferably during June through July when they lose regenerative power. Spread weeds cut off around trees. It is effective for curbing the growth of other weeds, keeping the soil dry, protecting surfaces soil, and making it more fertile.

Cutting down after September should be avoided~~,~~ since it is a season when weeds have stored nutrients and trees are exposed to cold.

During the work, there is a chance of gravel or small piece of metals scattered from the cutting equipment. Thus, it is important to use safety goods and take account of working direction and position of workers around the working area, with paying attention to passing pedestrians and vehicles.



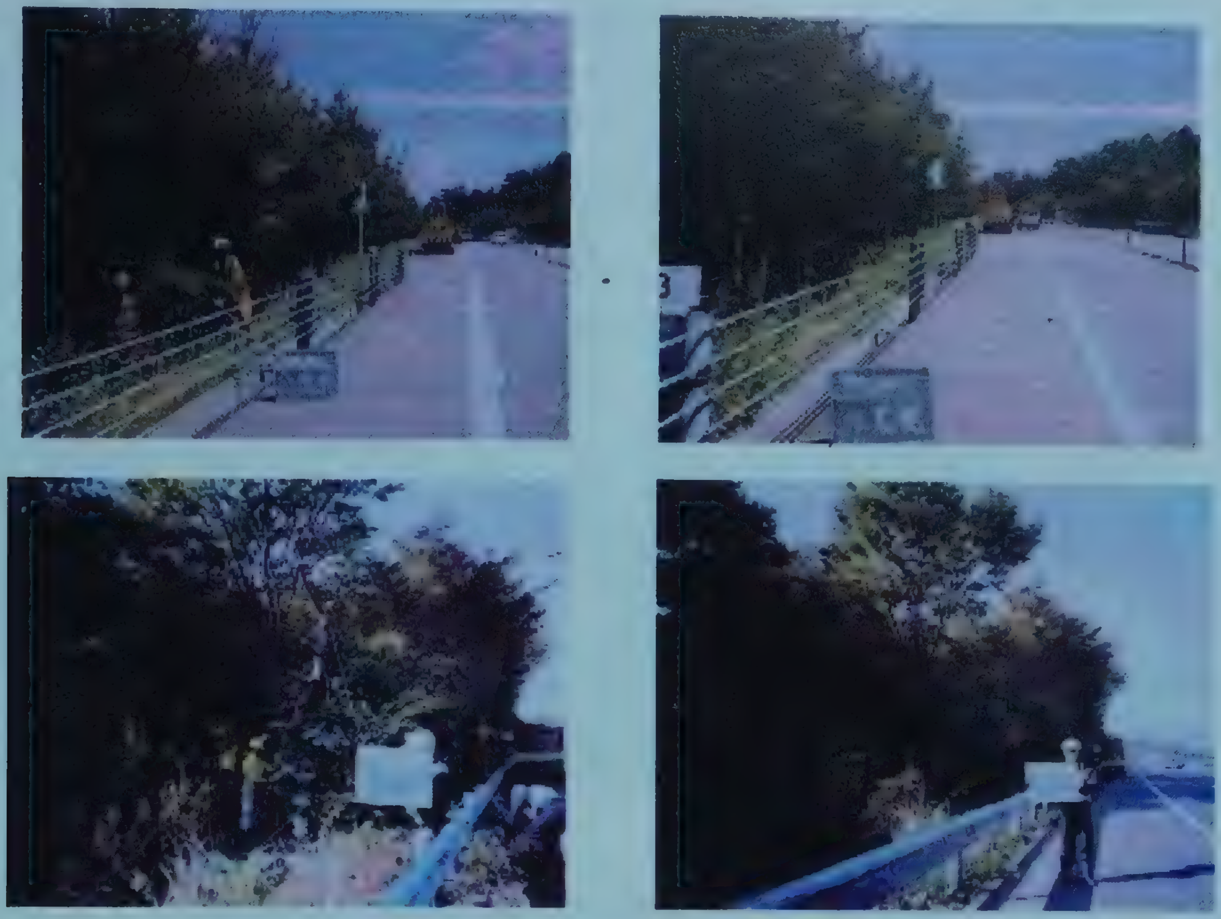
(a) During Work (b) After Work

[15]

Figure 6-17: Weed Cutting

(4) Felling of Selected Tree

Felling of selected trees, including thinning of forests and cutting obstructive trees where no obstruction exists around the trees worked, they are cut down at the base, and branches are removed. On the other hand, where there is any obstruction around them, trees are hung on the wrecker and cut off at the base, or Manually suspended from the pulley with branches to be removed first, followed by the trunks which are to be cut by 1 to 2 meters from the tip onward.



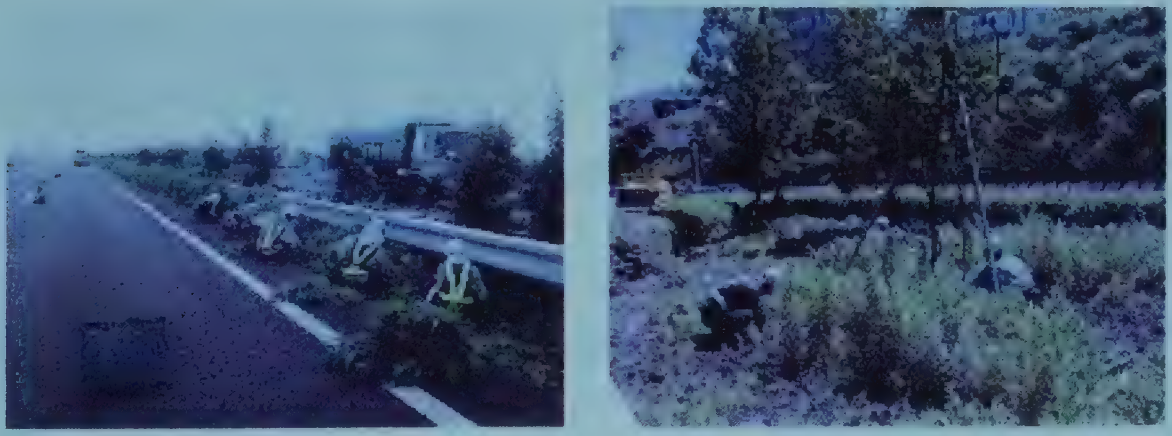
(a) During Work (b) After Work

[15]

Figure 6-18: Felling of Selected Trees

(5) Manual Weeding

This involves manual weeding of the ground around trees and turfed gardens. It is more effective if weeding is done during May through June for spring and summer grass and during July through August for autumn and winter grass to prevent inhibiting growth of trees and turfs, harmful insects, and malfunctions to safety equipment. It is important that weeds should be uprooted including capillary roots.



(a)Median Strips (b) Interchanges

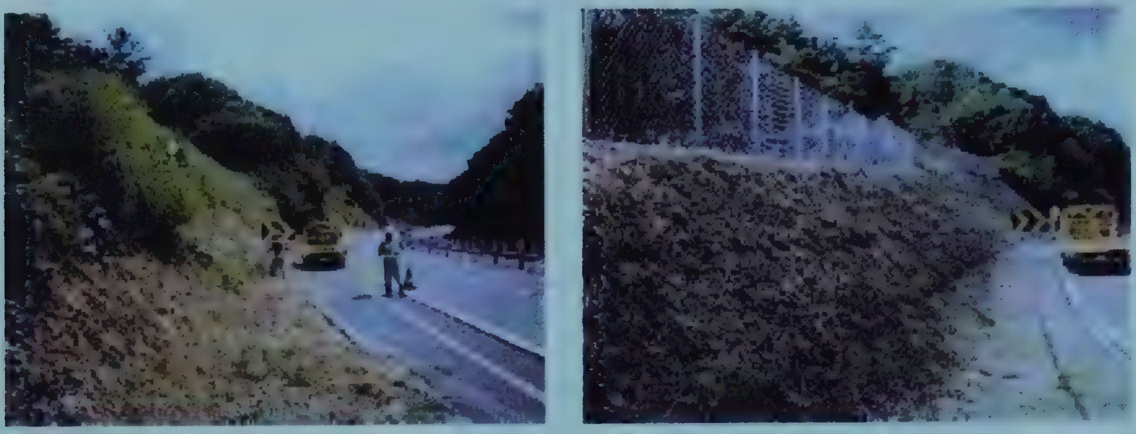
[15]

Figure 6-19: Manual Weeding

(6) Grass Cutting

This involves manual and mechanical mowing of part of the grassy area on the road shoulder and roadside cut or embankment slopes. The road administrator should pay attention to the following important points:

- Weeds cut off should be neatly packed into containers.
- Weeds left uncut after mechanical mowing should be neatly cut off by hand.
- Weeds should be cut off at any time as they can be a possible menace to traffic safety, cause fire, spoil visibility of delineators or exert an adverse effect on the nearby environment.
- Mechanical mowing can cause pebbles, metal fragments, etc. to fly at work sites. Therefore, remove them before mowing the area.



(a) During Work (b) After Work

[15]

Figure 6-20: Grass Cutting

There are largely three cutting methods from i) to iii) below:

i) Grass cutting (with shoulder-suspended grass cutter)

This involves mowing with a shoulder-suspended grass cutter.

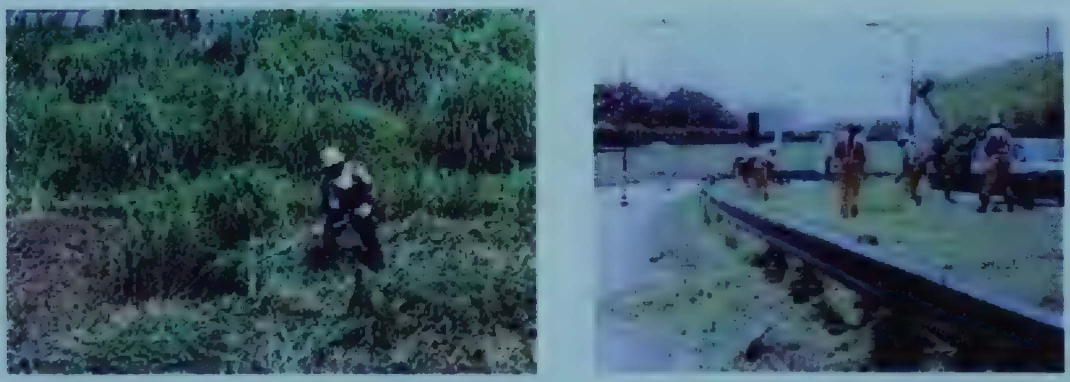


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Figure 6-21: Shoulder-Suspended Grass Cutter

ii) Weeding (with self-driven slope grass mower)

This involves mowing roadside slopes with a self-driven, remote-controlled grass mower.

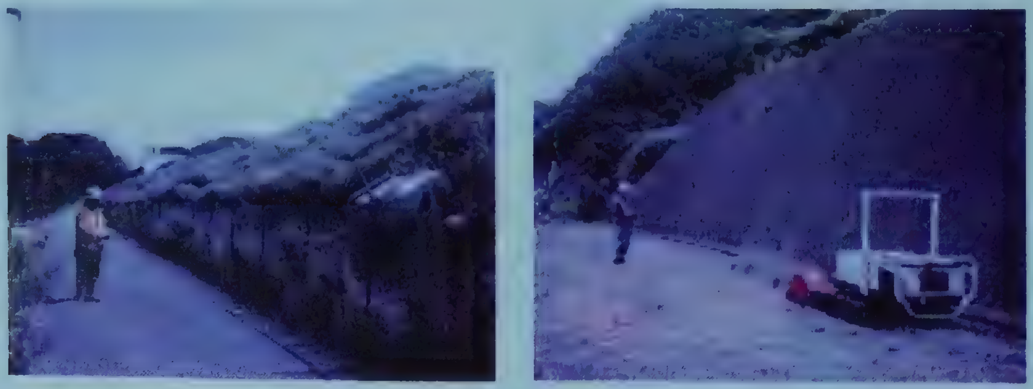

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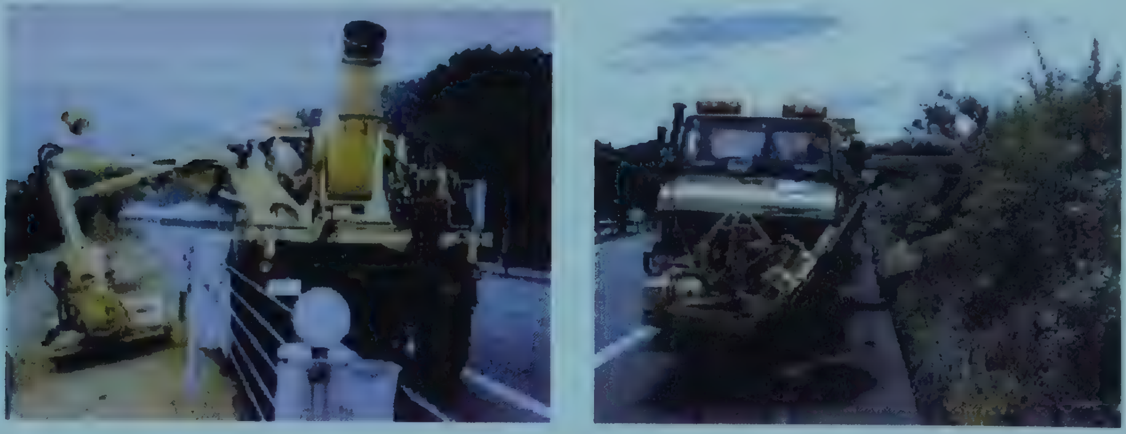
Figure 6-22: Self-Driven Slope Grass Mower

iii) Weeding (with the multi-purpose weeding vehicle)

This involves mowing roadside slopes with a general-purpose weeding vehicle.



(a) Embankment Slope (b) Cut Slope

[15]

Figure 6-23: Multi-Purpose Weeding Vehicle

6.4 Maintenance Repair Work

6.4.1 Purpose and Categories of Maintenance Repair Work

Mountainous highways serve a vital role for the regions where the highways pass. With the growth of the regions, the importance of highways has been getting higher and higher. In this regard, the road administrator shall put more emphasis on maintenance of the highways in order to maintain the roads in good condition by day-to-day inspection and investigation and by timely maintenance repair works. Maintenance repair work typically needs traffic regulation. In the case of sections with heavy traffic, congestion may occur, which leads to a decrease of service level for road users. Therefore, the road administrator shall formulate an adequate plan of the works including timing and methods, by taking account of a characteristic of concerned roads and sections, as well as repair methods to be applied. Moreover, it is necessary to scrutinize and develop safety plans by coordinating with related agencies, such as traffic police. It is advisable to refer to the section on traffic safety for its detail.

6.4.2 Types of Maintenance Repair Work

Maintenance repair work is largely classified into traffic accident recovery work and maintenance repair work. Traffic accident recovery work tackles damaged structures due to traffic accidents, which includes replacement of crash barriers, delineators, kilometer posts, traffic signs, etc. Readers are expected to refer to existing relevant guidelines and manuals for details. On the other hand, maintenance repair work includes repair works, which cover pavement, bridge, tunnel, traffic safety facility, vegetation, etc. as described in the following sections.

(1) Replacement of Bridge Bearings and Expansion Joint

- Bridge bearing

MoRTH Specifications for Road and Bridge Works published by IRC specifies different types of bearings generally used in structures such as steel bearings, elastomeric bearings, and pot bearings. These specifications aptly provide details for the execution and maintenance of the bearings.

- Expansion joint

MoRTH Specifications for Road and Bridge Works published by IRC provides the details regarding provisions, execution, and maintenance of expansion joints. However, the following as practiced in Japan are presented for illustration.

Current expansion joints are classified into three types as follows:

i) **Elastomeric joint**

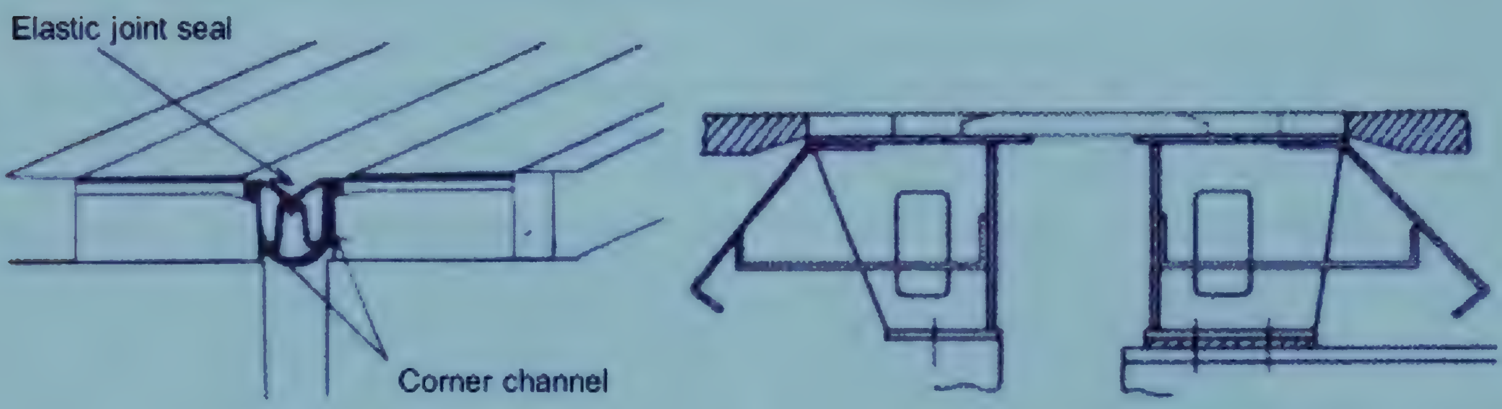
   It features a combination of elastomer with steel for application to concrete bridges. It is further classified into four types: elastomer-surfaced joint, steel surfaced joint, butt joint non-load bearing, and load-bearing joint.

ii) **Steel finger joint**

   It represents a comb-type expansion joint capable of directly bearing tyre load, as applied to steel bridges and concrete bridges with highly expandable beams.

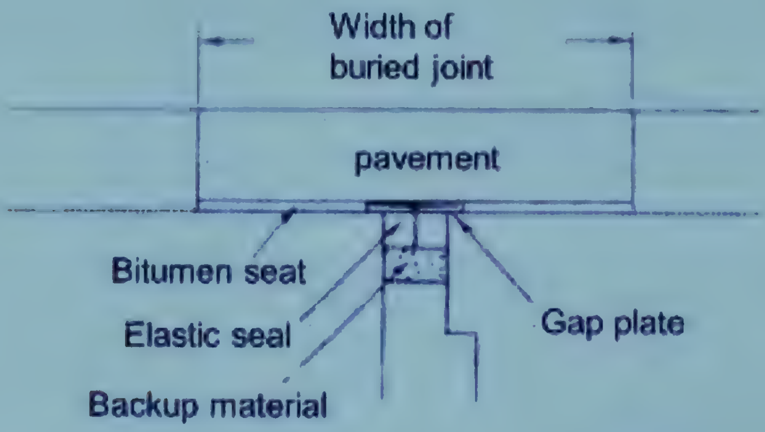
iii) **Buried joint**

   Expansion joint composed mainly of pavement materials, etc. having properties similar to those of neighboring pavements, commonly applied to concrete simple girder (on the fixed side) of a bridge.



(a) Elastomeric Joint

(b) Steel Finger Joint

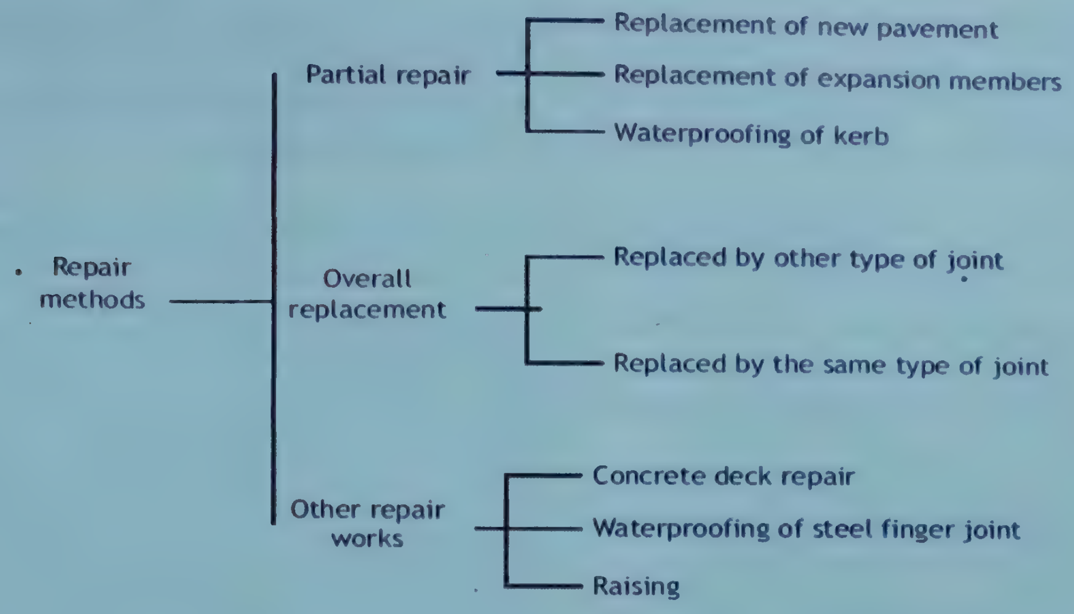


(C) Buried Joint

[15]

Figure 6-24: Types of Bridge Joints

Repair methods are largely classified into three types as shown in Figure 6-25.


Repair methods
Partial repair
Replacement of new pavement
Replacement of expansion members
Waterproofing of kerb
Overall replacement
Replaced by other type of joint
Replaced by the same type of joint
Other repair works
Concrete deck repair
Waterproofing of steel finger joint
Raising

[15]

Figure 6-25: Category of Repair Methods

For the repair of expansion joints, it is important to repair them as soon as possible after tracking the cause of damage. Also, the road administrator should develop a detailed work plan in full consideration of traffic regulations, where necessary. Moreover, it is preferable to repair damage to the concrete deck concurrently with joint renovation.

(2) Repainting of Steel Bridge

This work involves repainting on paint film deteriorated by rust, exfoliation, etc. as follows:

(i) Total painting: Repainting the entire surface
(ii) Touch-up (local): Applied to more deteriorated portions, for instance, lower flange base of girder and box girder due to various causes
(iii) Touch-up (spot): Applied to badly rusted portions due to water leakage caused by local damage to the welded part, expansion joint, decks, etc.

Since surface preparation by abrasive blasting can affect film durability more than any others, road administrators should make sure that extra care should be put in during the repainting work. The repainted surface should be entirely cleaned and polished. Also, workers should keep the following points in mind during the work:

- Remove decayed (dead) paint film without rust resistance
- Leave rust-preventive (active) film alone, unremoved
- Polish rusted portions until film bed (metal face) surfaces

Steel bridges are repainted primarily for rust prevention. In this regard, bridges should be coated to specified thickness in accordance with the design in every process of painting work.

Moreover, it is important to precisely determine the severity of film deterioration and select the right type of abrasives and painting method. Also, for the preparation of painting material, workers should dilute the paint with thinner to the desired viscosity by using thinner to a minimum required. In overlay coating, it is necessary to check to see if the previous coat has been dried up and to perform coating under prescribed temperature and humidity.

In case of coat work in a closed area such as a box girder, carefully coating such portions and taking extra precautions for the safety of workers is vital. Most hazardous in painting works are typically installation and removal of staging and regulations in respect of labor safety and hygiene, to safeguard workers.

On the step of installation of staging, workers install staging in ways to secure safety and allow efficient work. In the case of local or spot touch-up, there is a case where mobile staging is used to save costs on works.

(3) Protection against Fatigue Damage on Steel Bridge

Fatigue damage can be repaired by welding, by welding, or by using splice plates as reinforcements. Weld mending is designed to restore the functions of the damaged portions by rewelding after the removal of cracks through grinding or gouging. This method is designed to restore the original state of the structure and is often combined with other repair methods. Splice plates are attached to reinforce damaged parts, thereby increasing the resistance area and flexural rigidity, and reducing the stress and deformation of the damaged part. High-tension bolts are used to fix splice plates.

(4) Improvement of Bridge Shoes

Failure of bridge shoes is mainly caused by:

- Superstructure-to-shoes connections
- Substructure-to-shoes connections, or
- Direct damage to the shoes

There are two methods of improvement of bridge shoes, which are replacement of shoes and rustproofing of shoes (coating with sprayed zinc).

- Replacement of shoes

Following the replacement of shoes, bridge structures are supported temporarily in order to temporarily release shoe reactions. Entire or partial shoes are replaced to restore their normal functions. For the temporary support of bridge structures, it is necessary to check the stress on the bridge structures and temporary supports, and the impact on transit.

- Rustproofing of shoes (coating with spray zinc)

Badly rusted shoes undergo surface treatment such as shot blasting, before the application of lubricants, rustproofing through the coating with spray zinc, and topcoat painting for recovery of their normal functions.

(5) Replacement of High-Tensile Bolts in the parts of Steel Bridge

This work involves the re-installation of high tensile bolts in the parts of a steel bridge where rivets or bolts have slipped off due to superannuation or vibration.

(6) Protection against Corrosion and Salt Damage on Concrete Bridge

Corrosion and salt damage are one of the common contributors to the degradation of bridges especially in snowy cold regions where salt is widely used to ensure a good driving environment in winter. This protection work aims to prevent corrosion and salt damage by surface coating, after rehabilitation of damaged sections, and cathodic protection, each of which is designed to impede the progression of corrosion. Infiltration of salinity into concrete structures may come from exposure to a coastal/marine environment or the use of sea sand or chemical admixtures containing a large number of chlorides, etc. Corrosion of steel in concrete can result in cracks, loss of adhesion with reinforcing bars, surface float, stripping, etc. For corrosion prevention, monitoring, and remedial measures IRC:SP:80 may be followed.

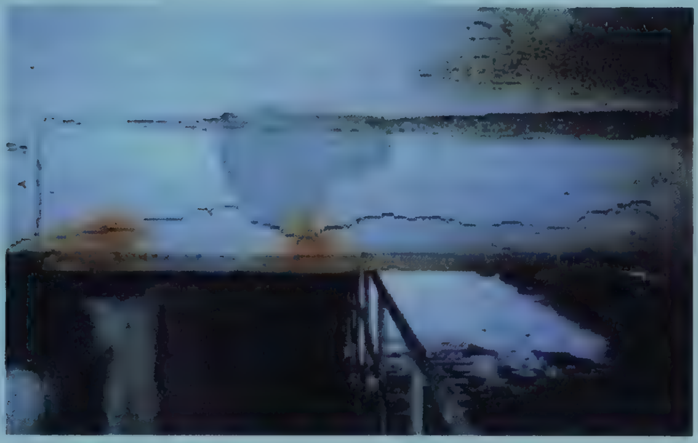


Figure 6-26: Concrete Cracks by Corrosion

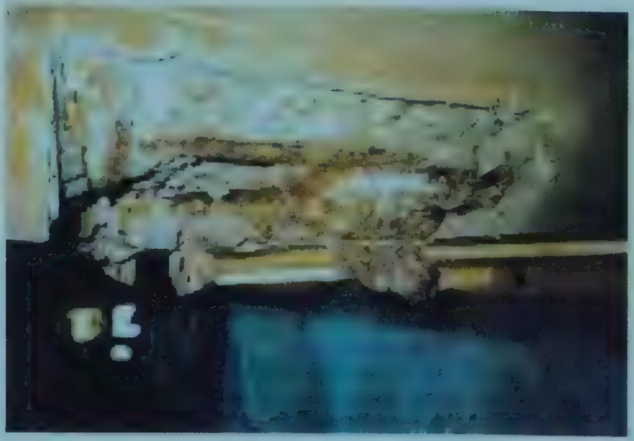


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Figure 6-27: Exposed Steel Rebar

The severity of the damage: The photo in Figure 6-28 shows concrete cracks triggered by infiltration of salinity on the concrete face, and by corrosion and dilatation of internal reinforcing bars, illustrating the presence of liquefied rusts.

Rustproofing chipped portions: If the internal reinforcing bars are entirely corroded, they are purged of rust and coated with a rust-proofing agent. Additional reinforcing bars are added as required. As a countermeasure, mortar is injected after molds have been placed on chipped parts.

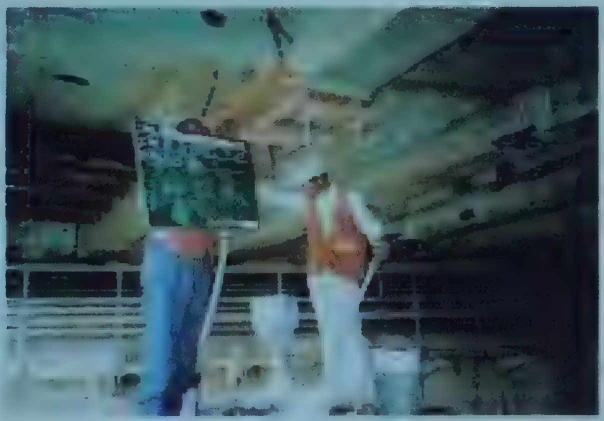

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Figure 6-28: Molds Injection

(7) Repair of Cracks on Concrete Member

Sealing of cracks in structures has been specified in the MORTH - Specifications for Road and Bridge Works published by IRC. This covers the materials, activities, equipment for injection along with testing and acceptance procedures. In Japan, permeable and adhesive synthetic resin or epoxy resin is pressure injected into cracks in concrete members.

(8) Partial Replacement of Bridge Deck

This involves the removal of existing pavements and decks and the arrangement of reinforcing bars on the mould laid beneath the decks. Where urgent construction is involved, use fast-setting concrete. Confirm concrete strength after curing.

The joint between the old and new floorings is a weak point in that it tends to permit water leakage. Accordingly, apply waterproofing works to cover overall joints including parts where decks are replaced. Photo shows liberated lime and trace of water leakage beneath the concrete decks of the steel bridge.

(9) Repair of Concrete Railing

This work involves rustproofing of reinforcing bars, repair of damaged concrete sections, and painting of a concrete face in order to prevent progression of corrosion of reinforcing bars rusted from local exfoliation, or thin covering of concrete railings.

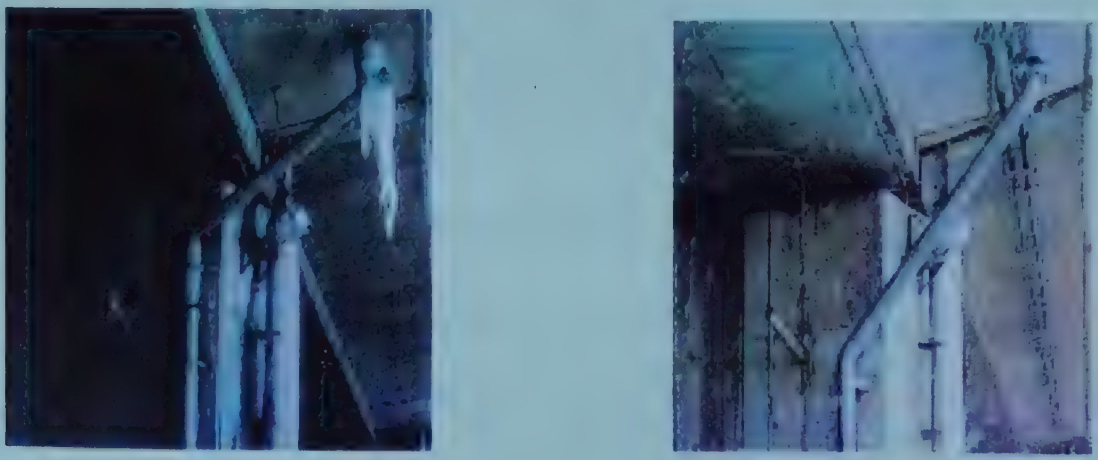
On the step of surface adjustment, it clears concrete faces of soils, dirt, and weak parts. Chipping aims to chip off concrete exfoliations, cracks, etc.

On the process of rustproofing, it removes rust from reinforcing bars and applies rust proofing materials, followed by the process of base treatment where primer and grading materials are applied.

In the process of renovation of the chipped section, chipped portions with grading materials are refilled to restore their original state. In the next process of filling, watertight and airtight base filler is applied to prevent deterioration of concrete and reinforcing bars. On the final step of the finishing coat, the finish coat is applied to reinforce the weather resistance of the base filler and preserve the scenic view.

(10) Replacement of Bridge Drainage

Depending on the shape of the drain pipe connections on a bridge, soil, sand, etc. can deposit on these connections to clog drain pipes. In this regard, drain pipes are improved to ease the passage of water by moderating bending. In snowy cold regions, accumulated water can freeze-dilate in winter, thereby cracking drain pipes and developing into icicles which inhibit the passage of water.



(a) Before Work (b) Completion

[15]

Figure 6-29: Replacement of Bridge Drainage

(11) Tunnel Water Leakage

The water leakage inside the tunnel is generally through the joints of precast concrete segments, faulty/cracked shotcrete, rock bolt connection, seepage through concrete lighting from rock/earth overburden. The water leakage treatment can be broadly grouped as (i) joint treatment for tunnels with lining and (ii) random treatment for tunnels without lining. A typical tunnel repairing in Japan is shown below:

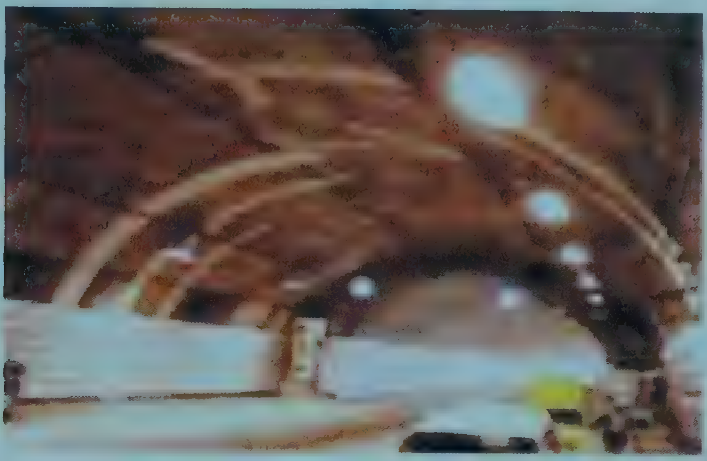


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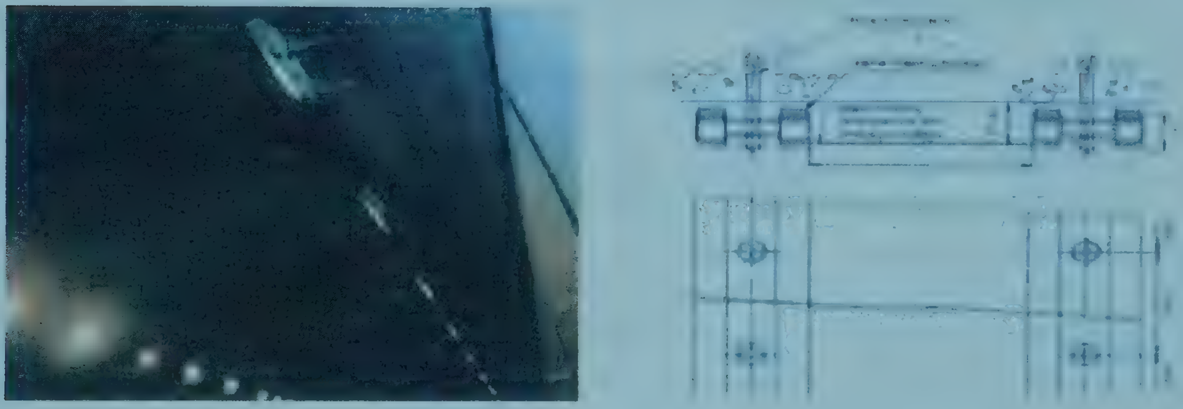
Figure 6-30: Typical Repair Arrangement on Leakage Area (Treatment of Sprayed Concrete)



[15]

Figure 6-31: Typical Repair Arrangement on Leakage Area (Joint Treatment for Lining)

6.5 Emergency Response for Disaster

It shall be described collapse-prone topography where it requires to be understood in advance. Then afterwards, brief flow shall be organized from the occurrence of disaster on slope surface to emergency measure or permanent measure.

6.5.1 Collapse-prone Topography

1) Overview

In the case of natural slope and cut, it is known that there is close causality with topography and collapse-tone. In regard to obtaining this topography information, it also requires professional technique or specialized knowledge other than aerial photo reading, field survey, etc. As for the easy reading of dangerous spot, a method focusing on the changes of contour interval of topographic map is raised.

Slope having certain width of contour interval whether narrow or wide is considered to have no problem with surface stability; however, the part where it is obviously wider or messed compared to the surrounding is considered as the part where some sort of deformation is seen in the past or wiggling bleeding channel exists, which the surface easily becomes unstable.

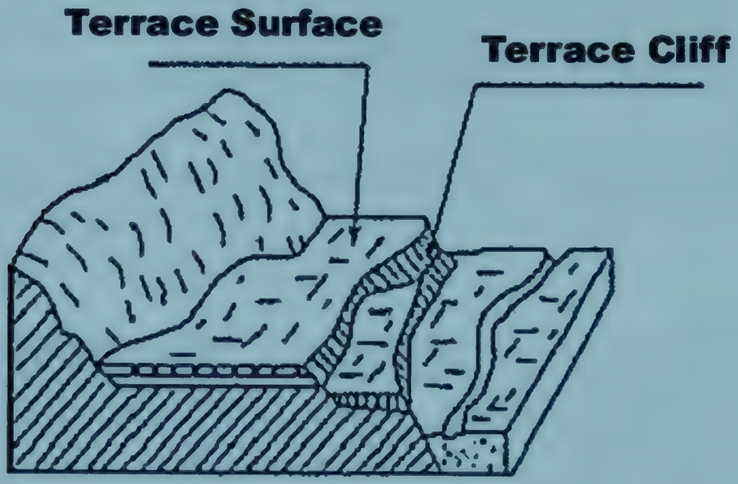
Dip slope means an incline of the discontinuous plane and slope surface of geological layer (bedding) etc., facing almost the same direction. The part where cohesive soil, etc. is placed between a thin bed boundary becomes the slope surface, and collapse of the slope is seen frequently. When a dip slope exists inside the slope, it is highly likely that soil outflows to the main lane.

2) Cut of alluvial fan

Alluvial fan means topography semi-conical shape facing downstream making the outlet where the river flows down from mountainous area to plain area. Alluvial fan mainly consists of sand gravel and because bearing resistance is big, no problem is seen as a fundamental ground; however, the underground water level is high depending on the location, for instance, permeability is high and quady at the alluvial fan or spring water is seen at the alluvial fan, it is necessary to pay attention to the section passing through the alluvial fan with cutting structure.

3) Cut on a terrace

When terrace gravel is deposited on the tertiary mudstone, it is necessary to pay attention to the easy collapse of the slope because the upper part becomes a permeable layer and lower part becomes a low permeable layer, and a large volume of underground water may centralize around the border.

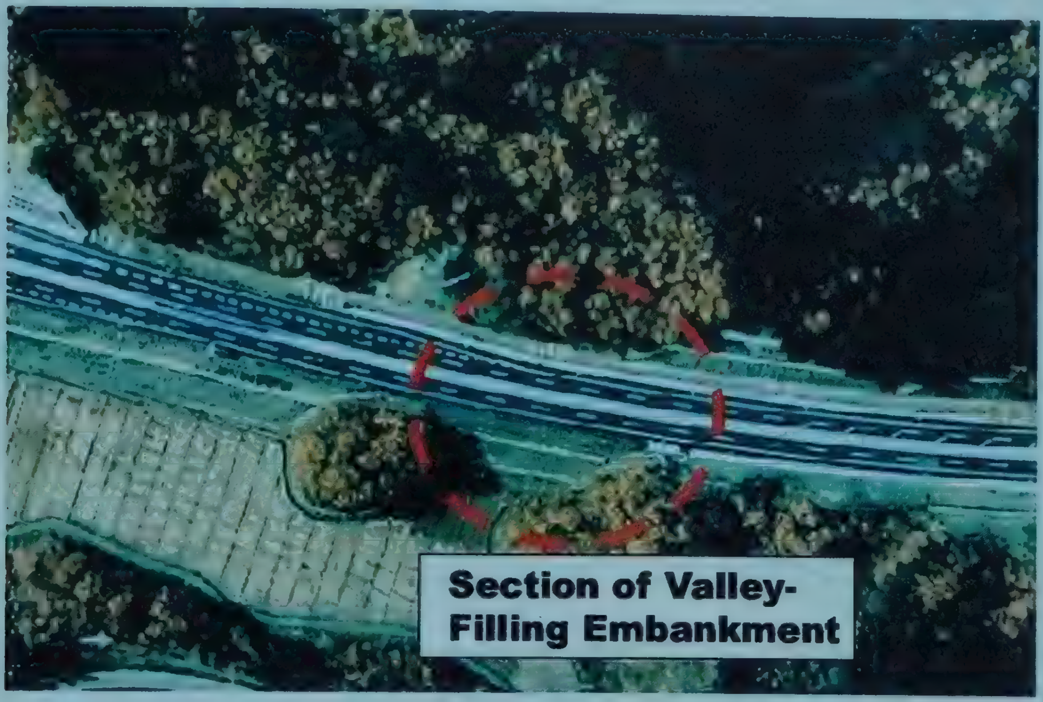


[19]

Figure 6-32: Underground Structure of Alluvial Plain

4) Valley-filling embankment

Because water centralize from the water catchment area on the valley (mountain stream), when it needs to pass these areas with embankment, underground water is likely to flow into the embankment from the border of earthwork or the surrounding ground. When the water level inside the embankment is high, spring water or mud may possibly appear in the slope, which hydrophilic plant, such as liverwort, is frequently overgrowing. In addition, the area where no snow is seen locally during the snow season might be influenced by spring water. Moreover, the viscosity soil layer (including peat layer) may possibly be thickly deposited on the surface at the valley (the drowned valley) and due to the depression of the fundamental ground, it may cause grain gradient abnormal. When an abnormality is found in the drain system, the retaining area on the road shoulder and in the water channel after the rainfall shall be immediately repaired because it possibly leads to downflow of scouring or soil and/or collapse of slope surface caused by floodwater or downflow inside the embankment slope.



[16]

Figure 6-33 : Example of Valley-Filling Embankment

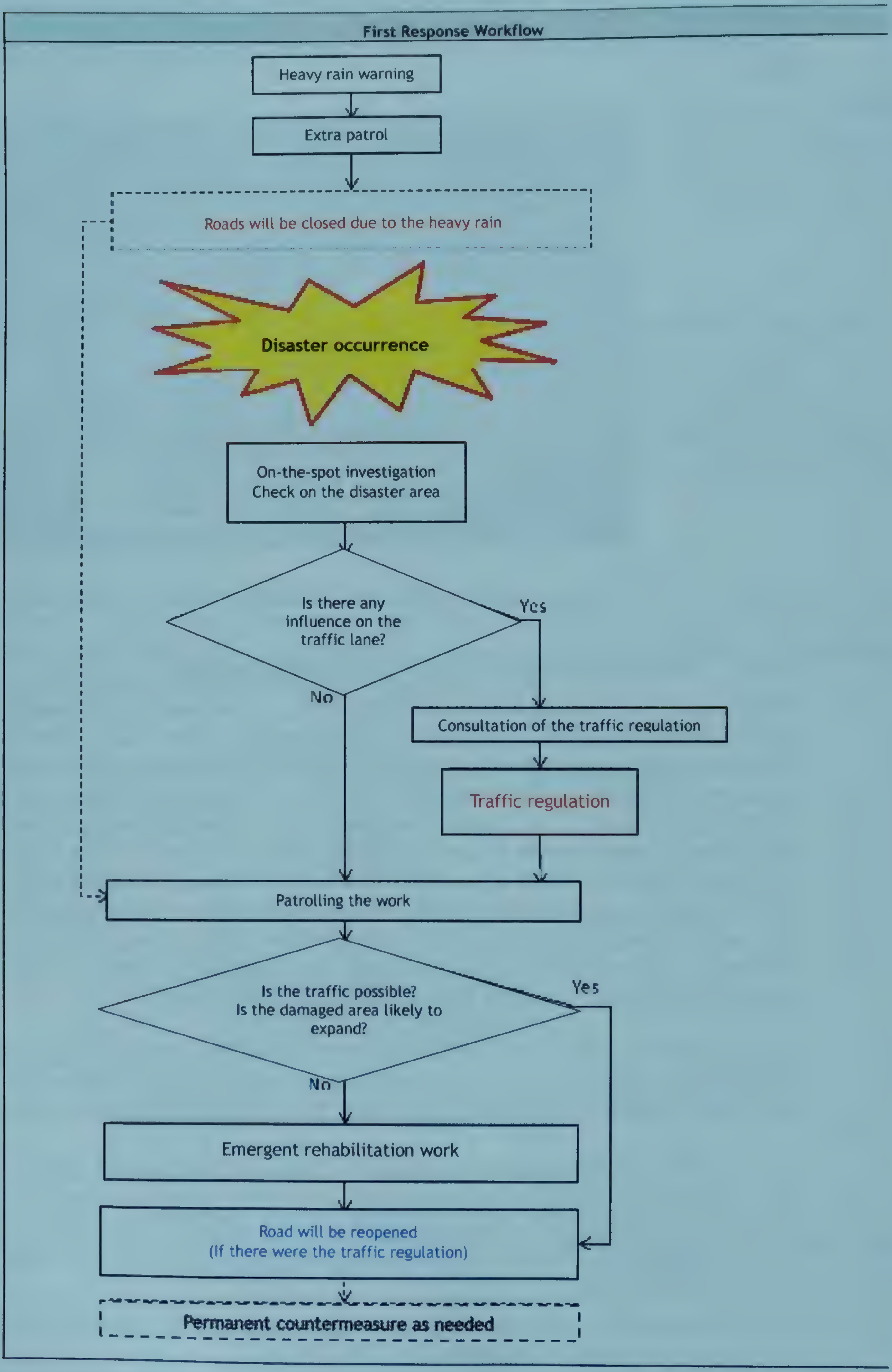
6.5.2 First Response at the Time of Slope Collapse

When slope collapse occurs, the influences on the lane are different depending on the areas where the collapse occurred. For example, in the case of the cut, soil caused by collapse easily flows into the lane because it is located on the upper side of the main lane, which makes some issues on the traffic. Therefore, it gives a big influence on the traffic lane even if it is a minor collapse. In the case of the cut, however, the traffic is sometimes possible even if comparatively major collapse occurs on the toe of the slope if it is no longer without any crack on the traffic lane. Therefore, the influence on the traffic lane is less compared to the collapse on the cut. When private houses, railways, etc. are located around the toe of the embankment slope, it is highly likely to cause damage on the third party and thus, it requires to keep in mind to perform an inspection on these sections at the time of heavy rainfall.

Figure 6-34 shows the idea of the first response when slope collapse occurs. In addition, the following points are the items which ~~an~~ attention is needed when patrolling the work and it requires to consider the traffic regulation or dangerous area setting.

- ✓ When the topography/geography of slope collapse area and its surrounding is the same or when continuous rainfall is observed, the damaged area may expand.
- ✓ In the case of a mountain stream or talus (talus sediment), the inflow of underground water from the surrounding is high and it is likely to expand the damaged area.
- ✓ When the crack occurs on the surrounding slope collapsed area, the damaged area is likely to expand.
- ✓ The out-flow range of colluvium at the time of slope collapse differs on the geological state of slope surface or collapse formulation, and slope protection

type as well as rainfall condition; however, the indication of maximum reach distance is the approximately double height of the slope.


First Response Workflow
Heavy rain warning
Extra patrol
Roads will be closed due to the heavy rain
Disaster occurrence
On-the-spot investigation
Check on the disaster area
Is there any influence on the traffic lane?
Yes
No
Consultation of the traffic regulation
Traffic regulation
Patrolling the work
Is the traffic possible?
Is the damaged area likely to expand?
Yes
No
Emergent rehabilitation work
Road will be reopened
(If there were the traffic regulation)
Permanent countermeasure as needed

[20]

Figure 6-34: Initial Response Flow at the Time of Slope Collapse

6.5.3 Emergent Rehabilitation Work

1) The idea of emergency rehabilitation work

When collapse or deformation is noted on the slope surface, emergency rehabilitation work is performed immediately, and then, a permanent measure based on the inspection shall be conducted afterwards in order to prevent damage on the third party, to secure road function as well as to prevent the expansion of deformation range. It is important for emergency rehabilitation work to determine the construction method by the degree of direct influence on the main lane.

The followings are the points to pay attention to for the emergency rehabilitation work.

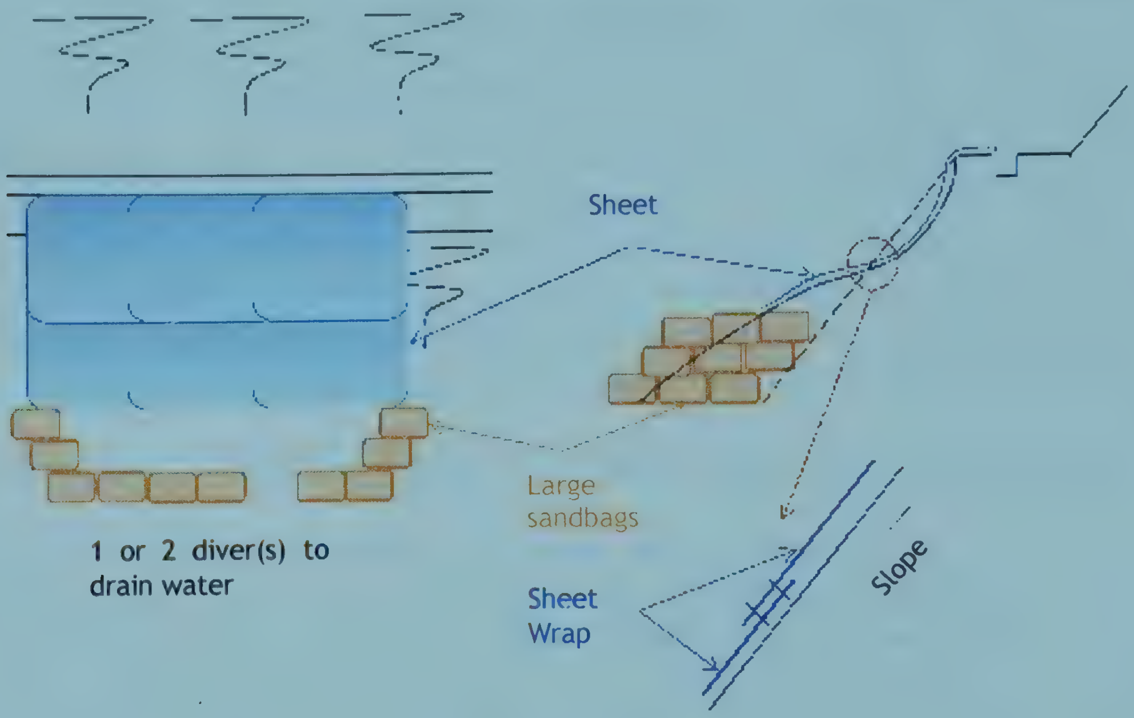
- ✓ If deformation range remains inside the slope and risk of influence is unlikely on the main lane, for the time being, curing sheets are necessary in order to prevent surface water, etc. entering into the deformation part until permanent countermeasure construction is performed. At that time, it requires to devise a way so that the water will not enter the layer of sheets or to place sufficient cover to prevent turn-up caused by the wind. In addition, it is important to repair drainage systems around deformation or to secure the cross-sectional area of flow.
- ✓ When progressive deformation is predicted to cause influence on the main lane or as for the response against the collapse which directly influences on the main lane, it is important to dispose of the surface water by placing diver as well as loading berm method by using a sandbag, mat gabion, etc. after removing collapsed soil immediately.
- ✓ Emergency rehabilitation work shall be ensured consistency with permanent countermeasure construction as possible, and it is important to make less reworking at the time permanent countermeasure is performed.
- ✓ When continuous rainfall is seen or when muddy water, a new crack around the collapse/changes or expansion on the crack occurs, it is highly likely that a new crack may occur and thus, it requires to prevent the secondary disaster by monitoring visually.

2) Example of emergency rehabilitation work

Once slope collapse due to rainfall occurs, it has a risk that the damage is likely to expand.

Therefore, it is important to dispose of the water appropriately after slope collapse and minimize the damage. Because of the above, the safety shall be secured for the traffic vehicles by placing large sandbags (place sandbags tightly against one another to form layers according to the scale of damage) and covering the collapsed slope. In addition, it sometimes increases the safety by placing sheet piles on the road shoulder part based on the scale of the collapse.

- ✓ Cover the surface of rupture by sheet
- ✓ Prevent the outflow of slided soil by sandbags
- ✓ Place 1 or 2 diver(s) in order to drain water from slided soil



[20]

Figure 6-35: Image of Emergency Rehabilitation Work

3) Stocks for emergency rehabilitation work

The followings are the recommended stocks for emergency rehabilitation work;

- ✓ Sandbags
- ✓ Sheets

4) Case of emergency rehabilitation work

When removing the colluvium, it may lose balance if the earth is removed from the lower part and has a high risk of collapse reoccurrence. When the main lane is buried due to colluvium at the time cutting slope collapsed, sliding cliff on the surface of collapse is generally becomes the heavy slope and in an unstable condition. Therefore, it is preferable to work on removing soil on the collapsed area after the sliding cliff is stabled. In addition, it requires monitoring the upper slope surface when working on the lower part.

[20]

Figure 6-36: Slope Monitoring at the Time of Boring

5) When earth retaining is performed

When it becomes unbalanced and has a risk of secondary disaster at the time slided soil is removed, earth retaining work is sometimes performed on the upper slope surface. Earth retaining work is assumed to be performed by sheet pile or solider pile and lagging method. If the sheet pile is placed where the underground water level is always high, dam-up may occur due to water shielding, which may promote instability. Therefore, it is important to pay attention to the influence of underground water and the marketability of the material.

6) Investigation method of slope surface

Understanding the scale of slope collapse and keeping a record of the presence of progression as well as deformation become the basic materials when considering the future necessity of permanent countermeasure and countermeasure construction. When performing an investigation, in addition, it enables to obtain valuable information from the material at the construction phase, aerial photo, etc. other than a topographic map of the relevant area, cross-sectional view, and profile.

It is important to investigate shortly after the collapse to keep accurate information. In this case, however, it is necessary to investigate after securing sufficient safety because it may enter into an unstable slope and has a risk of secondary disaster. When the visual investigation is performed, it shall be paid ~~an~~ attention to the following items in order to prevent the expansion of damage (accident).

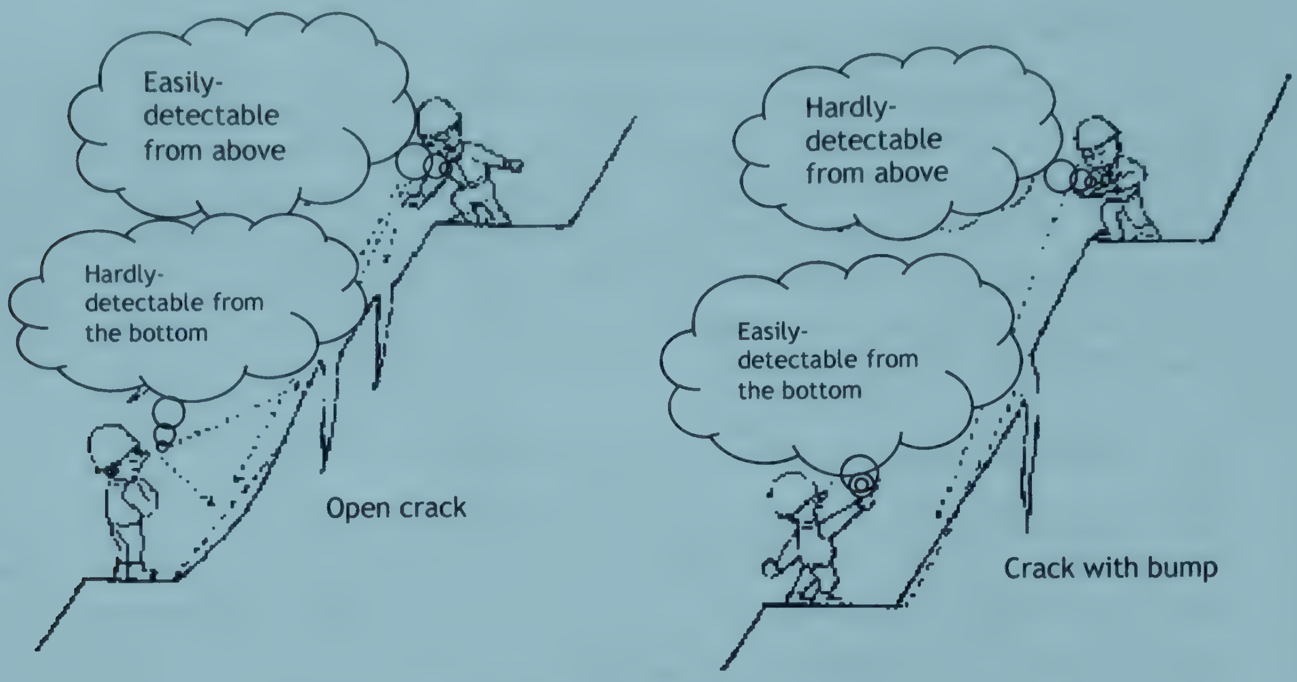
- ✓ When spring water is found on the collapsed part or small rocks are falling, it is preferable to keep a distance from the site.
- ✓ When a crack is found around the collapsed part, it is preferable to keep off away from inside the collapsed part.
- ✓ Because it is generally said that soil outflows to the triple distance of collapse, it is preferable to keep off the collapse area or toe of the collapse area.
- ✓ When investigating the collapse area, a guard shall certainly be placed.
- ✓ When performing an investigation, it shall secure an evacuation route (lateral direction from the collapse area) in advance.

7) Point for slope investigation

It is important to investigate the slope shoulder because most of the parts with slope collapse include slope shoulder. Because it sometimes misses the type, scale, direction, etc. of deformation by only 1 direction, in addition, it is important to trace the same route as an outward way on returning. A crack with a bump is generally detected easily from the bottom while an open crack is detected from above.

Because it enables to obtain comprehensive information by viewing from a high place such as facing slope surface, it is necessary to perform at the same time.

The upper top slope is sometimes located outside the road site in the case of a cut, it is also necessary to inspect outside the road because the crack on the upper side possibly leads to a major collapse.


Easily-detectable from above
Hardly-detectable from the bottom
Open crack
Hardly-detectable from above
Easily-detectable from the bottom
Crack with bump

[16]

Figure 6-37: Easy-Detection by Crack Type

6.5.4 Permanent Countermeasure Construction

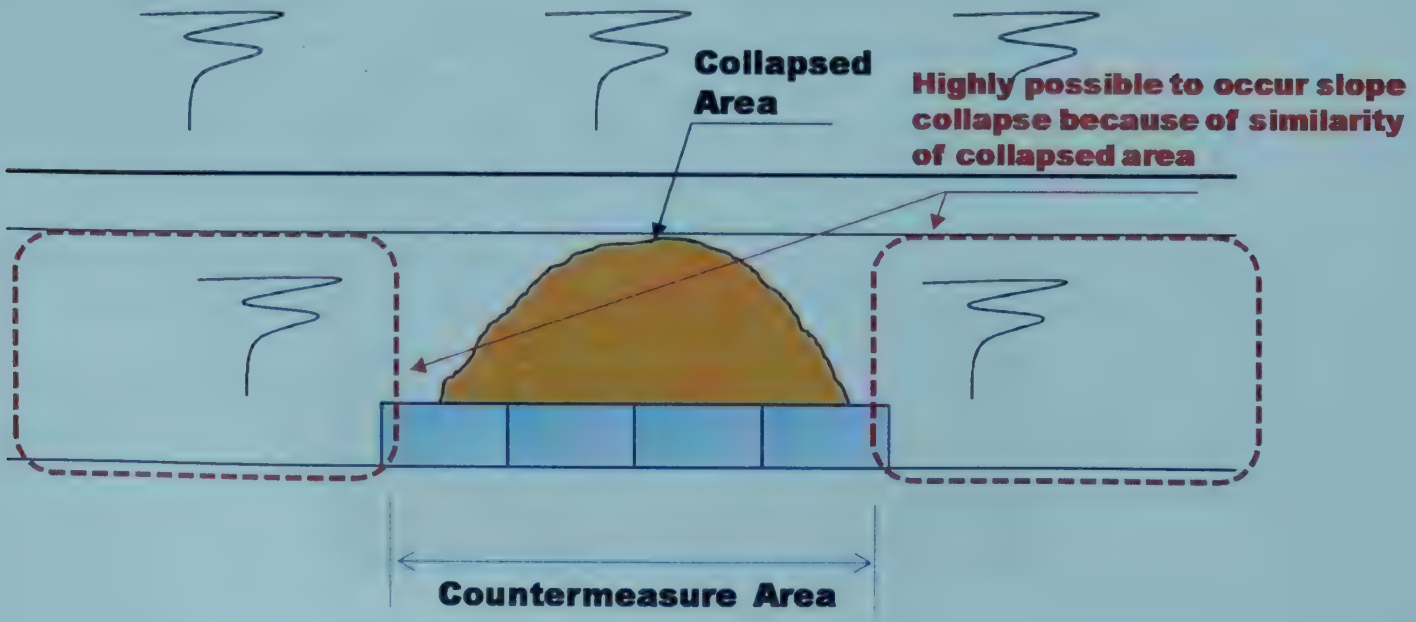
1) The idea of permanent countermeasure construction

Emergency rehabilitation work is performed in order to secure the traffic of the main lane where the slope was collapsed while permanent countermeasure construction is performed to return the performance back before collapse occurrence on the slope surface.

It is important to decide the method depending on the scale of collapse or deformation for permanent countermeasure construction. In addition, it is important to make less re-work by ensuring consistency with emergency rehabilitation work.

In the area where ground condition, such as geography or topography (including embankment material), is similar to where slope collapse occurred, it is highly possible that slope collapse may occur.

In terms of preventive maintenance, it shall consider reinforcement countermeasure for the nearby invariant area.


Collapsed Area
Highly possible to occur slope collapse because of similarity of collapsed area
Countermeasure Area

[16]

Figure 6-38: Outline of Collapsed Area in Invariant Section

2) Consideration in permanent countermeasure construction

The followings are the points to be paid attention to for permanent countermeasure construction (restoration work).

- ✓ Because the increase in water level with rainfall, scour due to abnormal drainage or outflow of soil is considered as the cause of slope collapse with rainfall, a priority is placed on strengthening of drainage function and improving drainage function around the toe of the slope.
- ✓ When backfilling is performed, it is recommended to use a material (gravel material) which enables to tolerate the outflow with permeability.
- ✓ When an abnormality is detected on the drainage system such as drainage slope or shear on the gutter, maintenance shall be performed because it is highly likely to occur scour or outflow of soil in the future.
- ✓ Because the road in service is the target, a construction method shall be conducted to minimize the influence on the main lane.
- ✓ Because additional land acquisition is the toughest part, the construction method shall be performed within the right of way.

As for considering permanent countermeasure, it is extremely important to find out the mechanism of slope collapse (factor/cause). In addition, the factor is frequently common in the area, it is necessary to pay attention to the similar collapse that may occur near the collapsed area.

Factor: Potential collapse-prone on the slope itself

- ✓ Geography (landslide configuration, catchment configuration, etc.)
- ✓ Topography (border between permeable layer and low-permeable layer/clay interbedded with bedrock, etc.)
- ✓ Geological structure (dip slope, fold structure, etc.)
- ✓ Drainage structure (poor drainage capacity, deterioration, etc.)

Cause: External cause that may be a trigger of slope collapse

- ✓ Earthquake (frequently seen on ridge topography)
- ✓ Rainfall (frequently seen on surrounding topography)
- ✓ Snow melting (frequently seen in heavy snowfall areas)
- ✓ Develop action of the hinterland (issue on the cut slope surface)

3) Major permanent countermeasure work

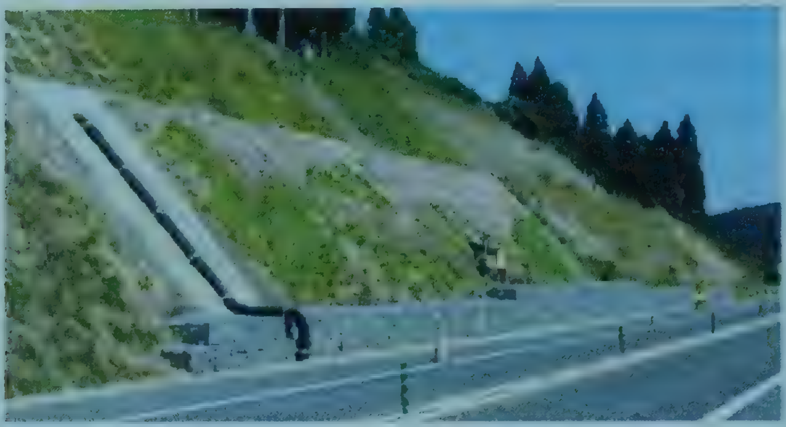
Slope surface countermeasure work is broadly divided into "control work" and "prevention work"; however, it is less adopted to use a large prevention work such as preventive pile or ground anchor for the surface collapse at 2 m or less collapse depth.

It is preferable to select control work in permanent countermeasure work. However, in case there is a limitation on ground or poor deterrent, it requires determining to take proper steps such as using prevention work concurrently. Permanent countermeasure work, in addition, is not necessarily one type but it is effective if several methods are combined.

The followings are examples of an assumed method for the permanent countermeasure of collapse on the surface layer.

- ✓ Counterweight work (cribwork of plating gabion)

  Although the cribwork of plating gabion has almost a similar structure to mat gabion, it is necessary to load by hand and has the advantage of shortening the construction period compared to mat gabion cribwork. In addition, because gabion itself has high stiffness and less deformation, it shall improve the working property or shorten the traffic regulation time other than the improvement of drainage function can be measured by loading gravel materials within the gabion.



[20]

Figure 6-39: Countermeasure Work by Gabion

- ✓ Underground water removal work (Horizontal drainage boring)

  It shall be performed with the purpose of removing from the comparatively depthless area from the land surface and carrying out pitch at 5 to 10 m. The diameter of the drill hole isφ66 mm or above, and a strainer hole retaining pipe (PVC pipe) is inserted. An approximately decrease at 1 to 3 m in-ground levels is generally expected. Because it is frequently closed due to soil or water scale, however, it requires periodic cleaning.

  Recently, a space-saving method has been developed such as strike-inserting strainer steel pipe tube "permanent drain reinforcement (PDR method)" or "simple boring method" in which extensive scaffolding is unnecessary.

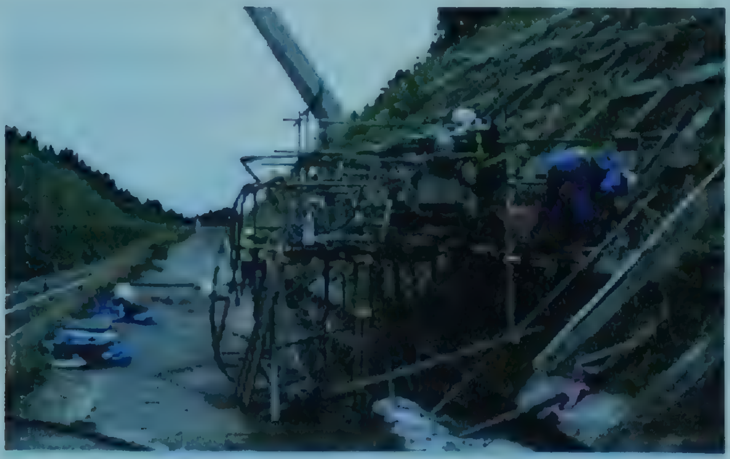


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Figure 6-40: Horizontal Drainage Boring

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